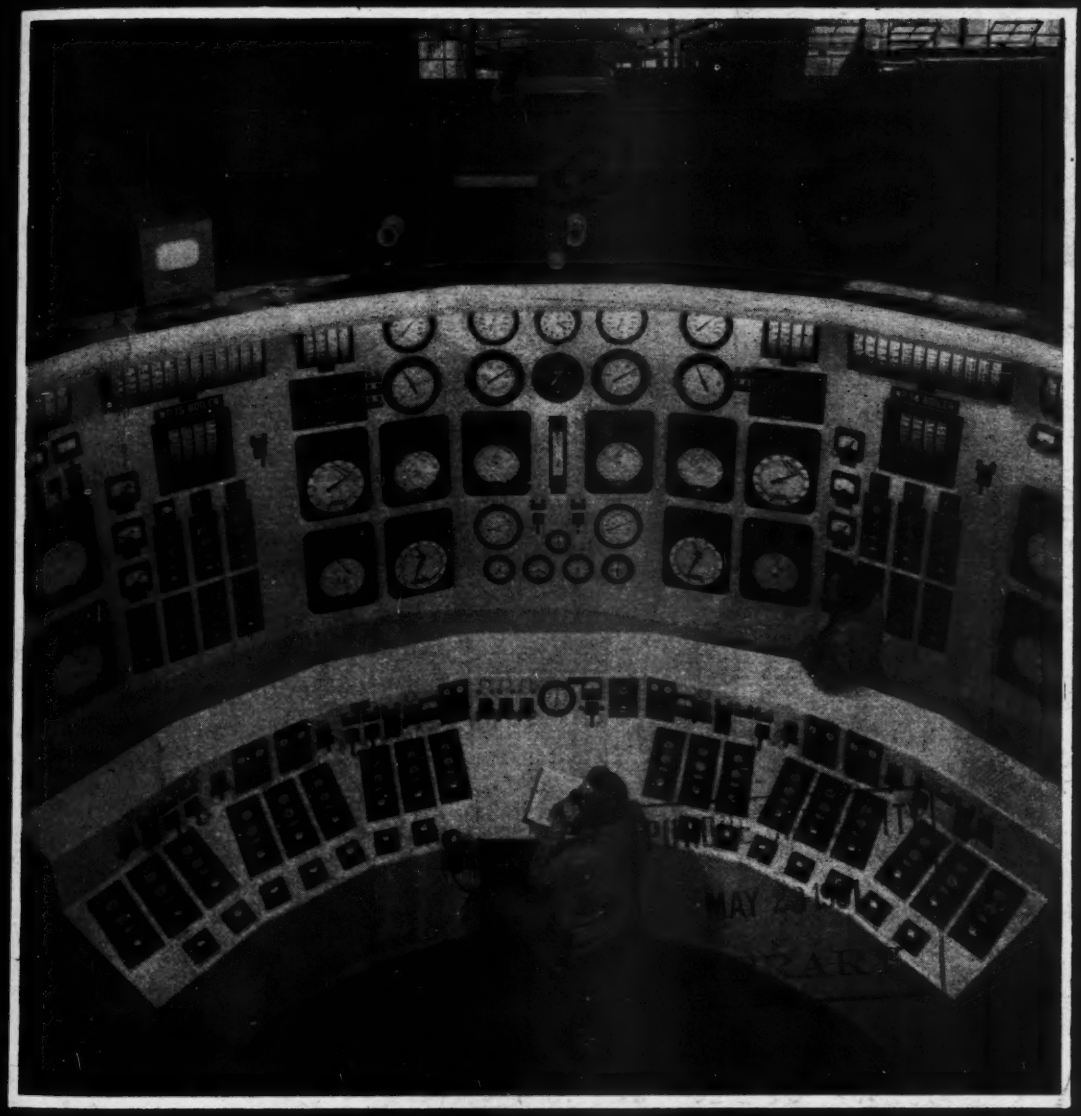
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 MAY 1951 No. 5

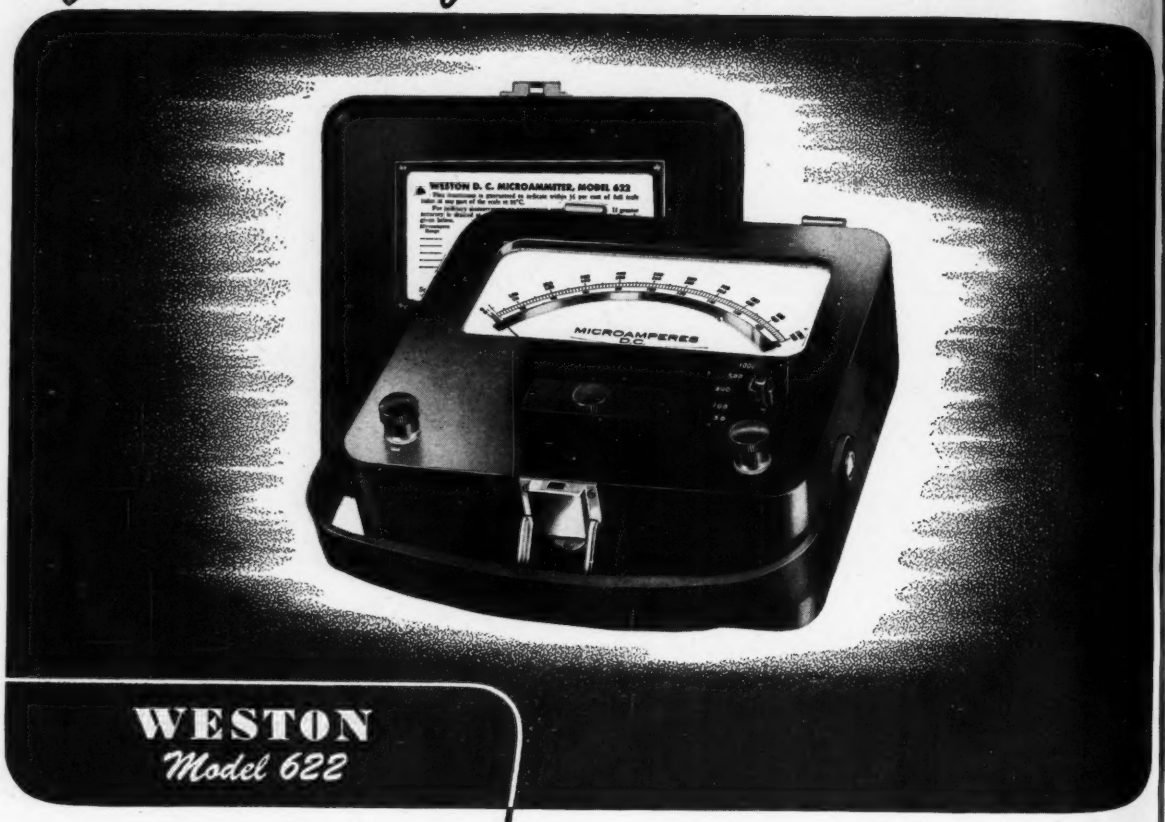
INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*



Control board at Dow Chemical Company's South Power Station at Midland, Mich. Upright board holds recorders and indicators for boilers. Console controls combustion system. See page 568. *(Photo courtesy Fulstrom Co.)*.

High Accuracy AT LOW ENERGY LEVELS



WESTON
Model 622

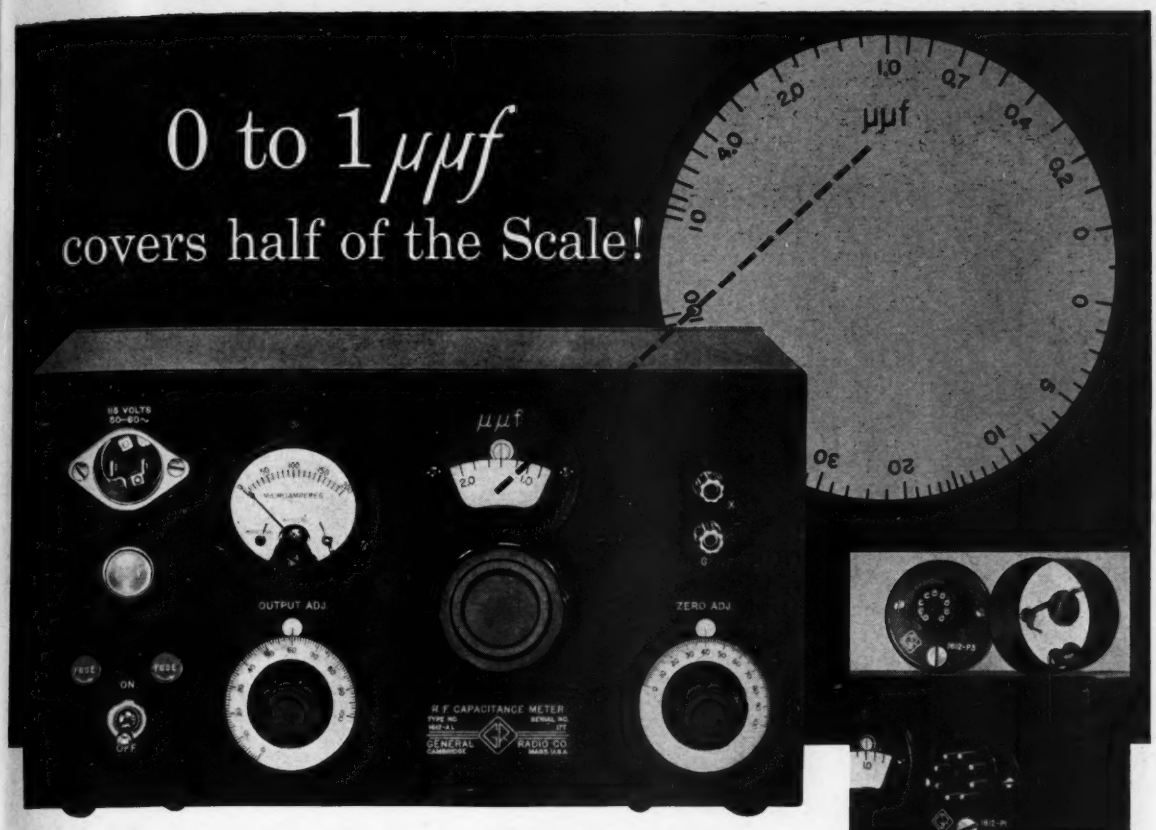
High sensitivity
• PORTABLE •
Instruments

Combining extreme sensitivity with high accuracy and a 6.1 inch scale, Weston Model 622 instruments are ideally suited for precise measurements of potential and current at the very low energy levels encountered in nuclear physics, electronics and electro-chemical research or in general test work. Hand calibrated, double pivoted, electrostatically and magnetically shielded.

These instruments are available as d-c voltmeters, millivoltmeters, milliammeters and microammeters; electrolysis voltmillivoltmeters and high resistance voltmeters. They are also made as thermocouple ammeters, milliammeters, and voltmeters; and as a-c rectifier type instruments. For technical data consult your Weston Representative, or write Weston Electrical Instrument Corporation, 606 Frelinghuysen Avenue, Newark 5, New Jersey . . . manufacturers of Weston and TAGliabue instruments.

WESTON *Instruments*

0 to 1 $\mu\mu f$ covers half of the Scale!



The measurement of very small capacitances at radio frequencies is sometimes a difficult problem. To simplify this important measurement, G-R has developed the Type 1612-AL R-F Capacitance Meter, having two ranges from zero to 10 micromicrofarads and zero to 100 micromicrofarads.

Compact, very simple-to-use, accurate and reliable, this new meter fills a demand for many measurements of small capacitances such as:

Ceramic Capacitors — tubular ceramics (insulated and uninsulated), disc-type ceramics, tubular ceramics included in v-t sockets

Molded Mica Capacitors — foil- or silver-mica

Variable Trimmer Capacitors — variable mica, variable plate-type, variable multi-cup-type air, variable ceramic, and variable piston-type with glass dielectric

Vacuum-Tube Sockets

The operation of the instrument is very simple. Merely: (1) set the main dial to one of its two zero points, (2) turn "Zero Adjust" dial for maximum meter reading, (3) turn "Output Adjust" dial for full-scale reading on meter. Connect the unknown to the "X" terminals and retune the main dial to obtain maximum meter reading. The capacitance of the unknown is then indicated directly by the main dial setting.

The capacitance accuracies are: LOW RANGE of 0 to 10 $\mu\mu f$: ± 0.03 $\mu\mu f$ below 1 $\mu\mu f$, and $\pm 3\%$ between 1 and 10 $\mu\mu f$; HIGH RANGE of 0 to 100 $\mu\mu f$: ± 0.3 $\mu\mu f$ below 10 $\mu\mu f$, and $\pm 3\%$ between 10 and 100 $\mu\mu f$.

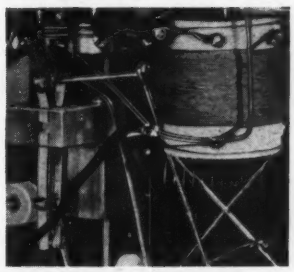
On the 10 $\mu\mu f$ range, the first $\mu\mu f$ occupies almost one-half of the scale length, and settings can be made to 0.002 $\mu\mu f$!

In addition, the meter can be used to approximate the dielectric loss by observing the amount by which the final tuning adjustment during measurement fails to reach full-scale on the indicating meter.

Together with its companion Type 1612-A R-F Capacitance Meter (with ranges of 0 to 1200 $\mu\mu f$ and 0 to 80 $\mu\mu f$) this new meter provides an unusually simple, accurate and direct method for measuring capacitances over a very useful range, at radio frequencies.

TYPE 1612-AL R-F CAPACITANCE METER ... $170
TYPE 1612-A R-F Capacitance Meter 170

For the measurement of r-f capacitance of tube sockets, these adaptors are required. Three are available: Type 1612-P1 for 7-pin miniature sockets, to measure "No. 4 contact to all"; Type 1612-P2 for octal sockets, to measure "No 4. contact to all"; Type 1612-P3 for 9-pin miniature noval socket, to measure "No. 5 contact to all." The adaptors fit into and shield around the "X" terminals on the meter. They are priced at $9.00 each.



In shifting from one range to another, no extra panel switching is required. The change in range is accomplished automatically as the dial is rotated from one half of the scale to the other, the switch shown above automatically performing the operation.

GENERAL RADIO Company
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OHMITE JAN-TYPE WIRE-WOUND RESISTORS

MEET REQUIREMENTS OF JOINT ARMY-NAVY SPECIFICATION JAN-R-26A

STYLES AND SIZES

TAB-TERMINAL TYPE

†Characteristics G and J

Style	Overall length	Diameter	*Watts
RW-29	1-3/4"	1/2"	8
RW-30	1"	19/32"	8
RW-31	1-1/2"	19/32"	10
RW-32	2"	19/32"	12
RW-33	3"	19/32"	18
RW-34	3"	29/32"	30
RW-35	4"	29/32"	38
RW-36	4"	1-5/16"	60
RW-37	6"	1-5/16"	78
RW-38	8"	1-5/16"	110
RW-39	12"	1-5/16"	166

TAB-TERMINAL TYPE with terminal hole to clear No. 8 screw

†Characteristics G and J

Style	Overall length	Diameter	*Watts
RW-40	3"	29/32"	24
RW-41	4"	29/32"	32
RW-42	4"	1-5/16"	49
RW-43	6"	1-5/16"	74
RW-44	8"	1-5/16"	100
RW-45	12"	1-5/16"	160
RW-46	10-1/2"	1-5/16"	135
RW-47	10-1/2"	1-9/16"	145

FERRULE-TERMINAL TYPE

†Characteristics G and J

Style	Overall length	Diameter	*Watts
RW-10	11-7/16"	1-5/16"	140
RW-11	9-5/8"	1-5/16"	116
RW-12	7-7/16"	1-5/16"	86
RW-13	5-1/8"	1-1/16"	58
RW-14	4-7/16"	1-1/16"	48
RW-15	2-15/16"	3/4"	20
RW-16	2-3/8"	3/4"	14

FLAT (Stack Mounting) TAB-TERMINAL TYPE

Characteristics G and J

Style	Overall length	Width of Core	Thickness of Core	*Watts
RW-20	2-1/2"	1-3/16"	1/4"	15
RW-21	3-1/4"	1-3/16"	1/4"	22
RW-22	4-3/4"	1-3/16"	1/4"	37
RW-23	6"	1-3/16"	1/4"	47
RW-24	7-1/4"	1-3/16"	1/4"	63

AXIAL-TERMINAL TYPE

Characteristics G and J

Style	Length of Core**	Diameter	*Watts
RW-55	1-3/8"	5/8"	5
RW-56	2"	5/8"	10

**2-1/2" wire leads

*Watts free air JAN Characteristic "G"

†Also meet requirements of Characteristics F, H, E, and D which were recently removed from Spec. JAN-R-26A. (Amend. 2)

Ohmite offers an unusually complete line of resistors that meet the most rigid requirements (Characteristics "G" and "J") of Joint Army-Navy Specification JAN-R-26A. To meet these requirements, resistors must pass severe moisture resistance and thermal shock tests. They are required to withstand strenuous vibration applied for five continuous hours. And, they must satisfy the requirements of many other tests, including momentary overload, mechanical strength, and terminal strength.

Of the 38 different resistor styles listed in JAN-R-26A, Ohmite offers 33 styles that meet these specifications. These styles represent the most popular resistors, and are available in a complete range of resistance values, in the types and sizes listed.

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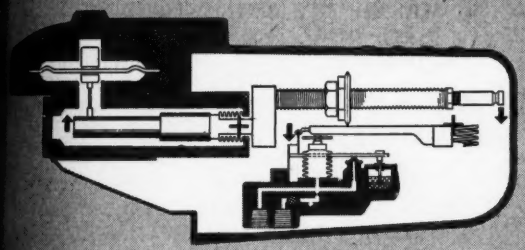
(pneumatic-balance flow transmitter)

Easy Field Calibration –without water column

No Strainers Required



Functional schematic cross-section of the Brown Differential Converter . . . showing its utilization of the pneumatic-balance principle.

Easily Cleaned

Wide Rangeability –in one unit, 20 to 200" H_2O

Fast Speed of Response

Easy to Install

No Mercury or Seals

AFTER long and rigorous testing in the field, the Brown Differential Converter is ready to set new high standards of simplicity and precision in the measurement and transmission of flow.

Operating on the pneumatic-balance principle, this compact and lightweight unit converts differential pressure at the orifice into a proportionate output air pressure which is a measure of flow. Range is continuously adjustable, from 0-20 to 0-200 inches of water. All adjustments are easily and simply made, without special tools or extra parts.

Applicable to a wide range of continuous processes, the Brown Differential Converter is the forerunner of an entirely new series of pace-setting developments made possible through Brown *Creative Instrumentation*. For detailed information write for a copy of new Catalog 2281 . . . and call in our local engineering representative for a discussion of your process needs. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

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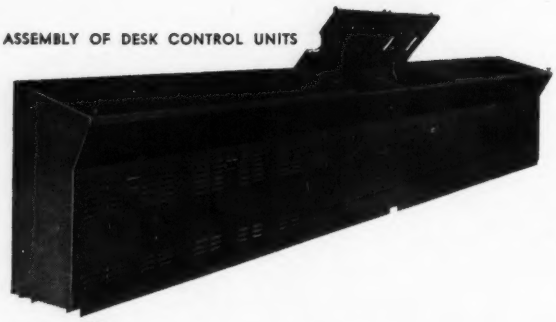

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☐ GAGE BOARDS
☐ CONTROL CENTERS

Instruments
THE MAGAZINE *of*
MEASUREMENT
and CONTROL

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Copyright 1951 by The Instruments Publishing Company, Inc. Office of publication, 1600 North Main St., Pontiac, Illinois. Executive and Editorial Office, 921 Ridge Avenue, Pittsburgh 12, Pa.

Entered as second class matter, October 14, 1949, at the post office at Pontiac, Illinois, under the act of March 3, 1879.

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TO AIR FORCE SPECIFICATIONS

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2" Single shown with removable Bezel. For exhaust temperature, range 0 to 1000°C, Chromel-Alumel.

2¾" Dual shown with removable Bezel. For exhaust temperature range 0 to 1000°C, Chromel-Alumel.

2" Single, for ring clamp mounting. For cylinder temperature, range −50 to +300°C, Iron-Constantan.

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12 or 24 volt ratiometers

2" Single, range −70 to +150°C oil temperature indicator, for ring clamp mounting.

2" Single, range −50 to −50°C for carburetor-air temperature indication, ring-clamp mounted.

2" Single, range 0 to 190°C for oil temperature indication, ring clamp mounted.

Available in all standard ranges for cylinder head, bearing carburetor-air, coolant, oil, free-air and heating-duct temperatures. For best results, use LEWIS resistance bulbs as sensing elements with LEWIS instruments. Any of above instruments may be supplied with type A-1 bezel if specified.

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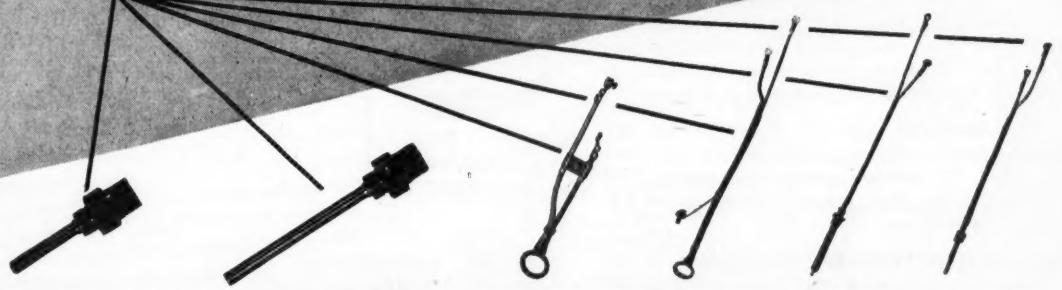
FOR BEST RESULTS USE LEWIS INSTRUMENTS WITH LEWIS BULBS AND THERMOCOUPLES



STANDARD AN5525-1 with 1⅞ in. stem | **STANDARD AN5525-2 with 4 in. stem** | **AN5540-1** | **AN5540-2** | **AN5545-1** | **AN5541-1**

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A CASE HISTORY OF WHY

- HIGH NATURAL FREQUENCY
- INHERENT FAST RESPONSE
- CONTROLLED READABILITY

ARE IMPORTANT ADVANTAGES OF THE EMERY

FORCE MEASURING SYSTEM

★ SIMPLE COMPACT PORTABLE

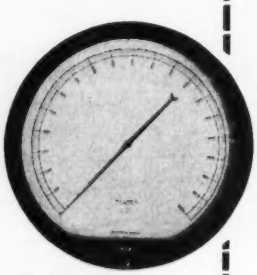
THE PROBLEM: A leading manufacturer wished to accurately read loads on a dynamometer for testing engines.

The torque measuring system they were using failed to provide accurate or usable readings; external vibration was present and the system went into resonant vibration at points where accurate readings were most desired. Even minor variations in the load produced erratic readings.

3/16 OD TUBING.

HOW EMERY SOLVED THIS PROBLEM

HIGH NATURAL FREQUENCY: A typical Emery cell has a deflection of less than .005" for full capacity and a high natural resonant frequency of 40,000 cycles per minute. This frequency was far above the external disturbing frequencies encountered in the above problem (and actually far above any such disturbances found in usual applications). A precise and steady dial reading is now obtained over the full range of testing speeds.



DIRECT READING IN POUNDS

FAST RESPONSE: With the Emery system, full scale indicator reading is obtained in less than ½ second. This inherent speed is unusual and important, but an even greater advantage of the Emery system is its

CONTROLLED READABILITY: Response of the indicator can be that of the inherent fast speed above, or it can be controlled by one simple Emery valve to follow and read load fluctuations, or to provide a steady reading of the mean value of a vibrating load. This control was another major factor in solving the problem described above, and in many other installations.

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Published by

The Instruments Publishing Company
921 Ridge Avenue
Pittsburgh 12, Penna.

Richard Rimbach, *Publisher*
Major M. F. Behar, *Editor*
Milton H. Aronson, *Managing Editor*
James F. Emge, *Assistant Editor*

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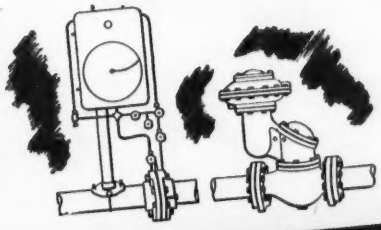

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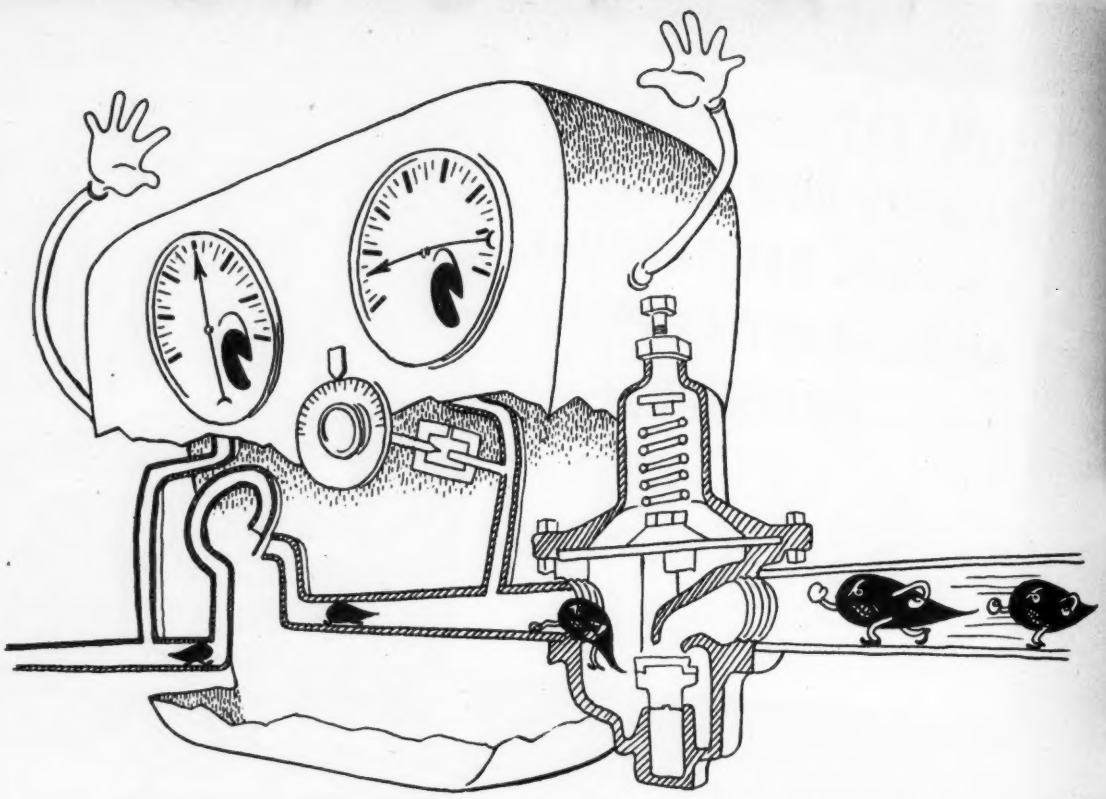

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It doesn't take much imagination to realize what's going to happen when those slugs of oil hit Mr. Instrument! You know how oil in compressed air instrument lines can foul-up production, cause down-time, and play havoc with maintenance costs. And the real tragedy is that oil in instrument lines just *isn't* necessary these days.

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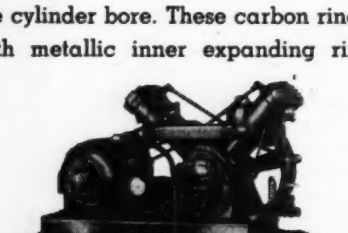
Here's your opportunity to cure a lot of maintenance and production headaches caused by oil slugs in instrument lines. Ingersoll-Rand has complete engineering data on NL Compressors that will interest you . . . including the 2 or 3 hp Model 235 HNL shown below plus other models available through 250 hp. Contact your nearest I-R representative, or write direct to Ingersoll-Rand Company, 11 Broadway, New York 4, New York.



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NL COMPRESSORS

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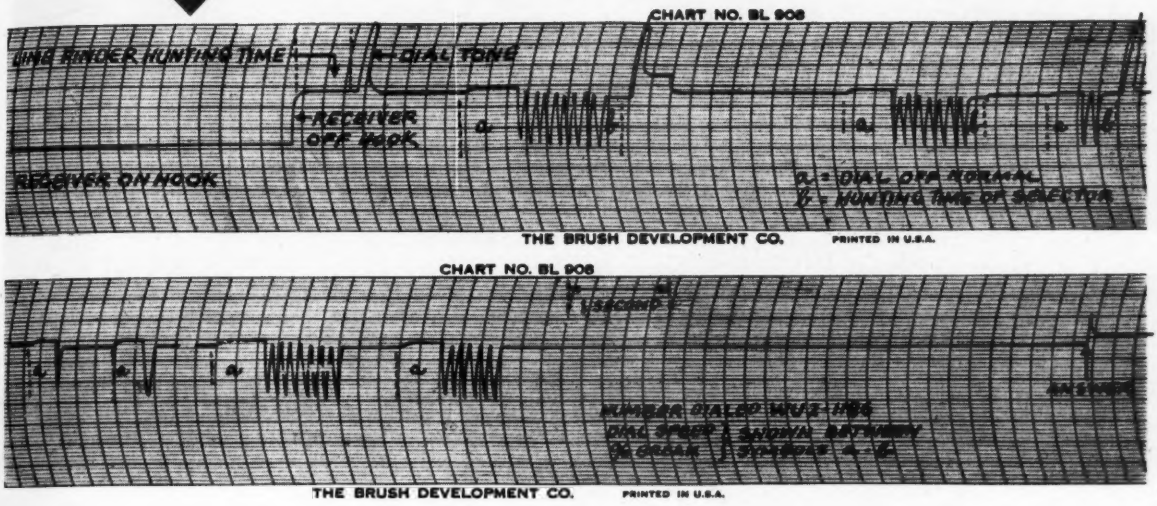
627-3

What's wrong with telephone WU 2-1186?



Fast relays checked by BRUSH Analyzer

A Brush Analyzer drew the graph above when one of the subscribers of an eastern telephone company picked up his phone and dialed WU 2-1186.

This record—drawn automatically in the time it took to dial the number—shows the timing and magnitude of every electrical impulse involved in the complex operation. Such records of impulses from the dials of both subscribers and operators provide the tip-off on equipments which require adjustment or repair.

This check on fast relay operation is but one of hundreds of investigations of electrical and mechanical phenomena which are being made speedily with Brush Analyzers. They record instantaneously. They simplify the study of strains, displacements, pressures, light intensities, temperatures, d-c or a-c voltages or currents.

Write for time-saving help stating your problems. The Brush Development Company, Dept. A-6, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A. *Canadian Representatives:* A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario.

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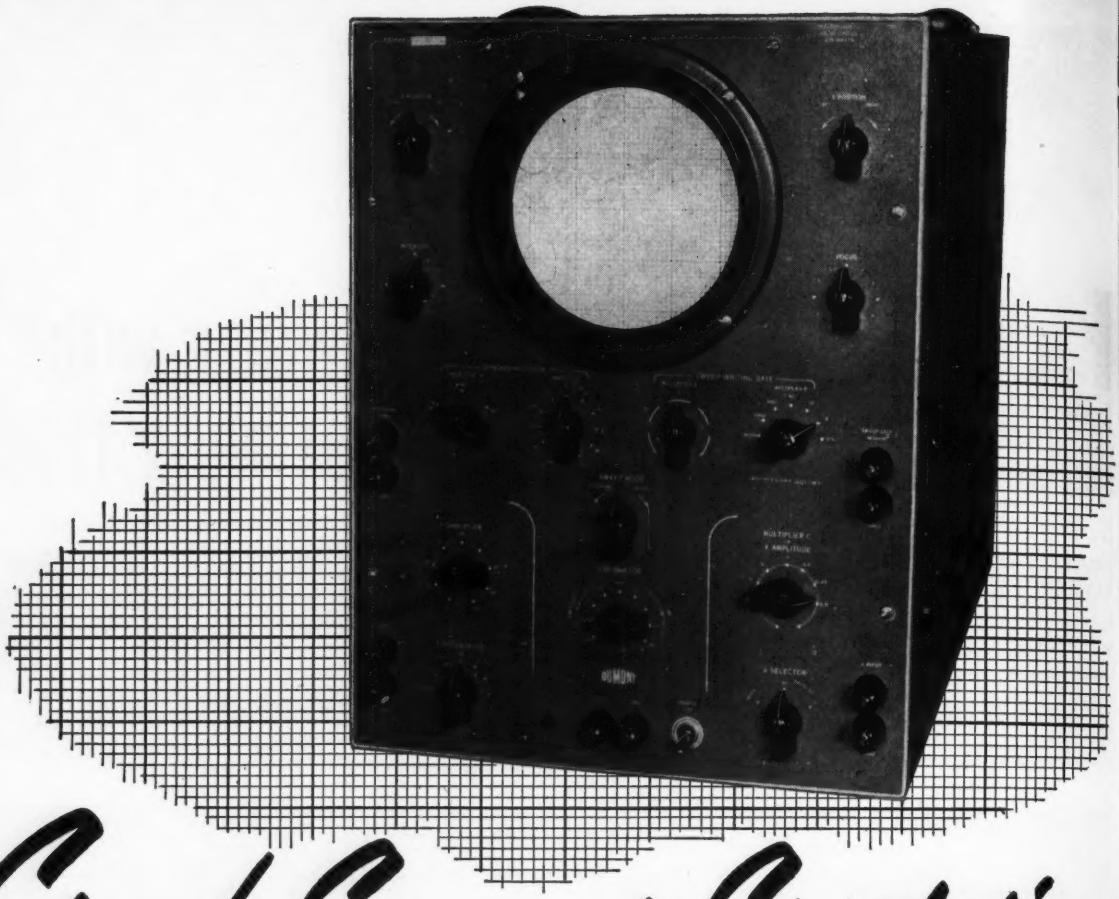

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by outperforming its own specifications...

Read the specifications of the Type 303 and you'll call it a 10-megacycle, quantitative instrument: operate the Type 303 and you'll realize you've sold it short. You'll find performance beyond the exacting limits of its specifications!

An exceptionally fine, medium-priced cathode-ray oscillograph, the Type 303 employs the new Type 5YP- Cathode-ray Tube. High sensitivity and an unusually wide range of sweep speeds make the Type 303 especially well suited for the study of high-frequency phenomena.

Using the equivalent of five inches of undistorted deflection on the Y axis, and six times full-screen expansion on the X axis, qualitative analyses can be highly detailed with the Type 303. Time and amplitude calibration add quantitative precision to this analysis, making the performance of the Type 303 unrivaled in the medium-price field.

Specifications

CATHODE-RAY TUBE — Type 5YP-

Y AXIS:

Sensitivity — 0.1 peak-to-peak volt per inch (down 30% at 10 cycles per second and 10 mc.) down 50% at 15 mc.
Pulse Rise Time — 0.03 microsecond.
Available Undistorted Deflection — 5" for symetrical signals and 2½" for unidirectional signals.
Signal Delay — Sufficient to allow for sweep-starting time.

X AXIS:

Sensitivity — 0.35 peak-to-peak volt/in. (flat to d-c down 30% at 500 kc).
Available Undistorted Deflection — 5"

SWEEP SPEEDS — up to 6" /μsec, obtained by expansion.

SWEEP DURATION — Continuously variable from 0.1 sec. to 2 μsecs. Driven or Recurrent operation.

VOLTAGE CALIBRATION — Square wave with peak-to-peak amplitudes of 0.1, 1, 10, and 100 volts. Accuracy ± 5%.

TIME CALIBRATION — Pulsed oscillations corresponding to time intervals of 100, 10, 1, or 0.1 μsec. Accuracy better than ± 3%.

INTENSITY MODULATION — 15 volts peak will blank the beam.

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Flow Signal Transmitter

. . . measures pressure or flow and transmits a proportionate signal to remotely-located recording or control devices.

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FLOW SIGNAL TRANSMITTER
HIGH PRESSURE TYPE
Transmits a pneumatic signal proportional to flow or differential. For static pressures up to 1500 psig. Full scale differential pressures from 5.5 inches water column to 100 psi.
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I-5

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AC VOLTAGE REGULATORS

Accuracy, with rugged construction, economical and trouble-free operation, reasonable cost — those are features that you expect, *and get*, when you specify Sorensen regulators!

ALL SORENSEN REGULATORS HAVE THESE ADVANTAGES:

- WIDE INPUT RANGE
- ADJUSTABLE OUTPUT VOLTAGE THAT STAYS SET
- REGULATION ACCURACY OF ± 0.1%
- EXCELLENT WAVEFORM
- FAST RECOVERY TIME
- INSENSITIVITY TO LINE FREQUENCY FLUCTUATIONS.

MODEL NO. 500-S

STANDARD AC SPECIFICATIONS

VA capacity	150 500	250 1000	2000 3000	5000 10000 15000
Harmonic Distortion	3% max.	2% max.	3% max.	3% max.
Regulation accuracy	± 0.1% against line or load			
Input voltage	95-130 VAC; also available for 190-260 VAC single phase 50-60 cycles			
Output voltage	Adjustable between 110-120; 220-240 in 230 VAC models			
Load range	0 to full load			
P.F. range	Down to 0.7 P.F. All models temperature compensated			

NOTE: THREE PHASE AND 400 CYCLE REGULATORS ALSO AVAILABLE. ALL REGULATORS CAN BE HERMETICALLY SEALED.

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For regulated DC problems investigate Sorensen's line of Voltage Reference Standards, DC Supplys, and NOBATRONS

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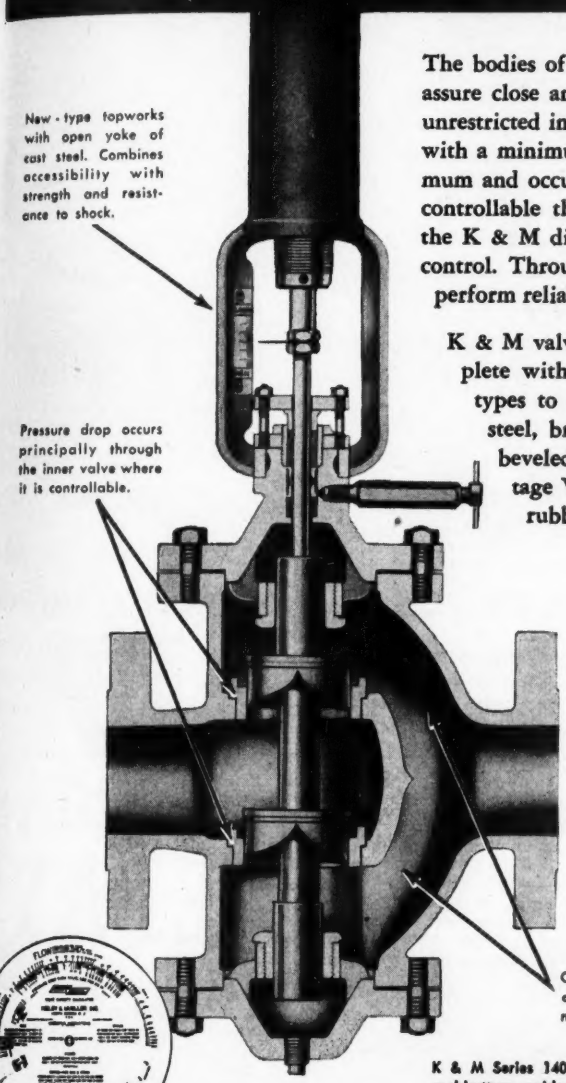
MANUFACTURERS OF AC LINE REGULATORS, 60 AND 400 CYCLES; REGULATED DC POWER SOURCES; ELECTRONIC INVERTERS; VOLTAGE REFERENCE STANDARDS; CUSTOM BUILT TRANSFORMERS; SATURABLE CORE REACTORS

The Control Valves DESIGNED ESPECIALLY FOR INSTRUMENTATION

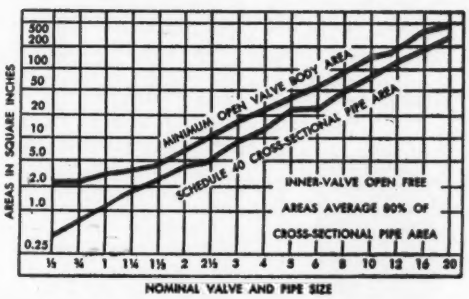

New - type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.
Pressure drop occurs principally through the inner valve where it is controllable.
Over-size, streamlined body areas reduce turbulence and friction to a minimum and assure smooth, maximum flow.

K & M Series 1400 top-and-bottom guided diaphragm motor valve.

The bodies of K & M Control Valves are especially designed to assure close and positive control by instrumentation. They have unrestricted inlet and discharge passages and permit smooth flow with a minimum of turbulence. Pressure drop is held to a minimum and occurs principally through the inner valve where it is controllable through the full valve travel. The construction of the K & M diaphragm motors assures extreme precision in this control. Throughout, K & M Control Valves are engineered to perform reliably in *the most exacting applications.*

K & M valves are available in sizes from ½ to 20-inch, complete with diaphragm motor and are made in 13 different types to meet varying requirements. Constructed of semi-steel, bronze, cast steel or special alloys. Inner valves in beveled quick opening, percentage parabolic or percentage V-port design as standard. Facings range from soft rubber to stellite.

Because of their modern design, all K & M valve bodies have extremely high capacities in relation to corresponding pipe size:



KIELEY & MUELLER

Established 1879

CHOICE OF THE NAVY FOR *Dependable Controls*

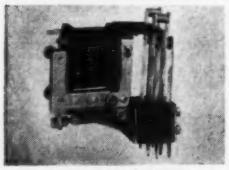
On peacetime boats of commerce and travel—on warcraft—Guardian Relays play major control roles, ranging from Marine radio to navy aircraft. The Series 335 D.C. *approved* Guardian Relay shown above is typical of Guardian units built to rigorous aviation standards. Meets the 10-G Vibration Test and the Mil-R-6106. Generous coil winding area permits single winding up to 15,000 ohms. Parallel and double windings available.

The Series 335 D.C. approved Guardian Relay packs loads of power over a wide operating range, withstands moisture, salt air, temperature changes, dust, vibration and impact. Available in standard open model or with A.N. Connector Plug, Octal Plug and Lug Header hermetic seal containers.

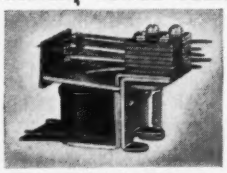
A.N. CONNECTOR PLUG HERMETIC SEALED CONTAINER

GUARDIAN RELAYS

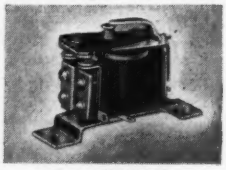
NEW CATALOG on Hermetically Sealed Guardian Relays with various containers is yours for the asking, cost-free.



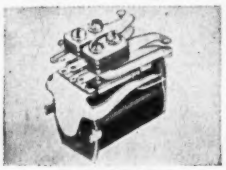
Series 30 A.C.



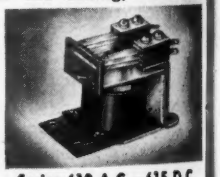
Series 210 A.C.—215 D.C.



Series 220 A.C.



Series 595 D.C.



Series 610 A.C.—615 D.C.

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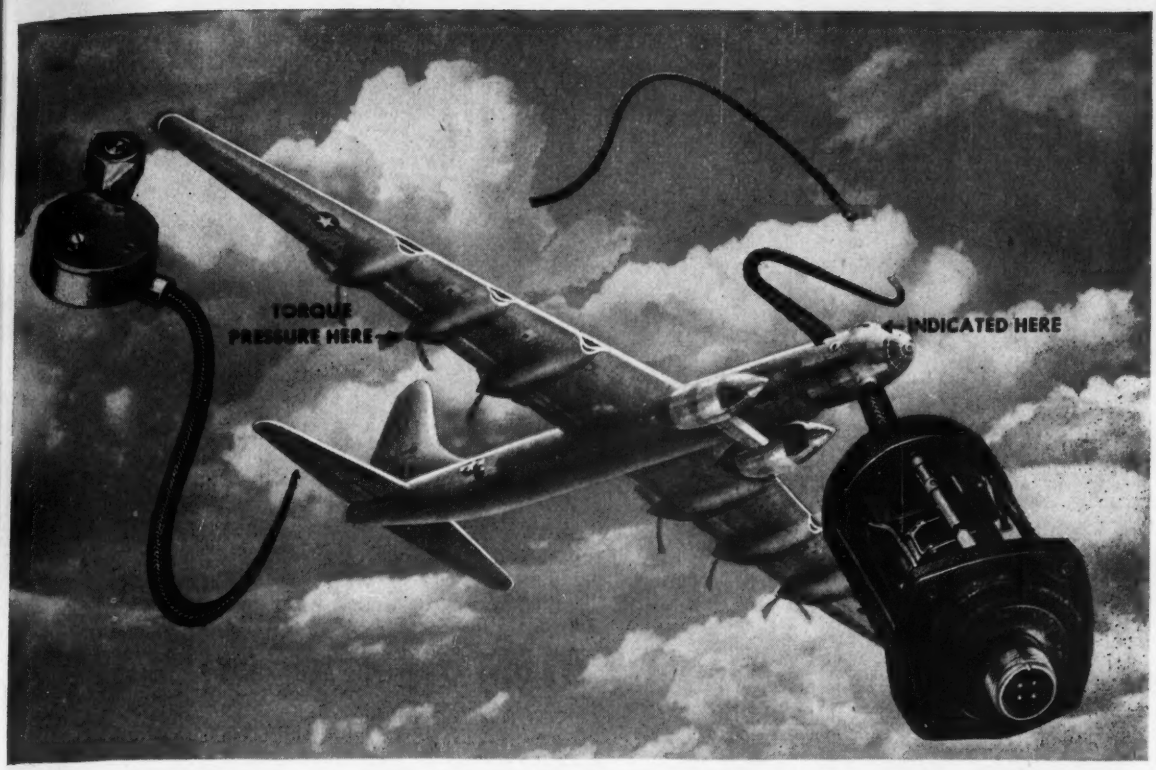

A NEW APPROACH IN AIRCRAFT TORQUE PRESSURE INSTRUMENTATION

Provides complete freedom from the attacks of sand, dust, fungus, salt fog and humidity

LOOK AT THESE EXCITING "FIRSTS" . . .

- Hermetically sealed and helium protected pressure and electrical elements.
- Nispan "C" pressure elements eliminating bimetallic compensation.
- Higher precision in remote transmission.
- Smaller and lighter in weight with tear-strip ease of disassembly.
- External adjustment through hermetic seal.
- Isolating link and pressure pick up for temperature extremes of −85 and +230 F.

In this Synchro Torque Pressure Transmitter one element measures the pressure and the other the ambient outside pressure. Together, these two Nispan elements measure the applied pressure in a sealed case charged with an inert gas, and transmit an electrical signal through a glass-to-metal connector.

This refreshing solution to a difficult problem leads a whole flight of new direct-connected clamp-on pressure indicators for oil, fuel, manifold, and hydraulic pressures.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

USG
Oil Pressure Gauge

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Fuel Pressure Gauge

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Manifold
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Quality Gauges Engineered for Enduring Accuracy

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PRODUCTS OF UNITED STATES GAUGE . . . Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude Gauges • Boiler Gauges, Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges

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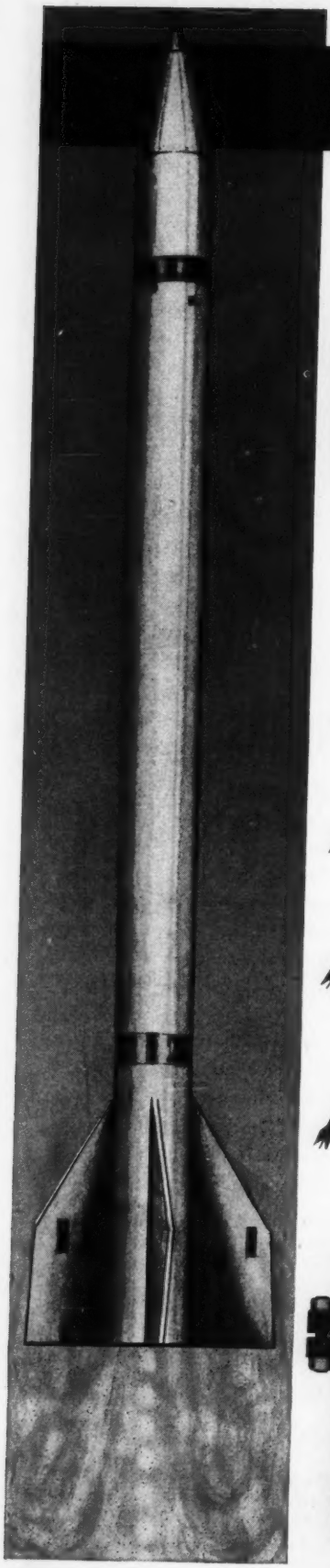

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FOR LIQUID LEVEL CONTROL TRANSMISSION and INDICATION

Improved Feature

New level set adjustment. More highly visible.

Improved Feature

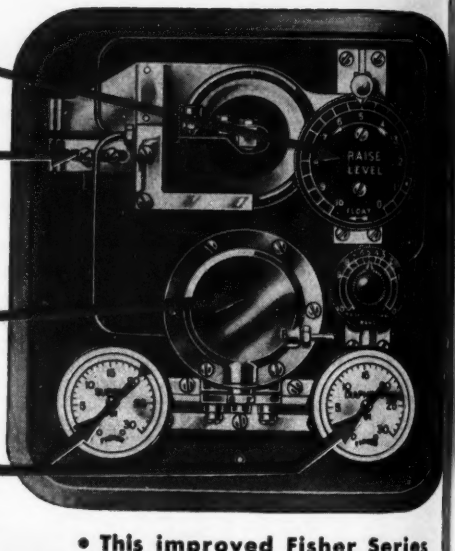
New factory calibrating adjustment makes possible accurate setting of proportional range over full float length.

Improved Feature

New relay—more compact—easily removed—easily assembled.

Improved Feature

Operating medium and diaphragm pressure gauges are glass-enclosed.



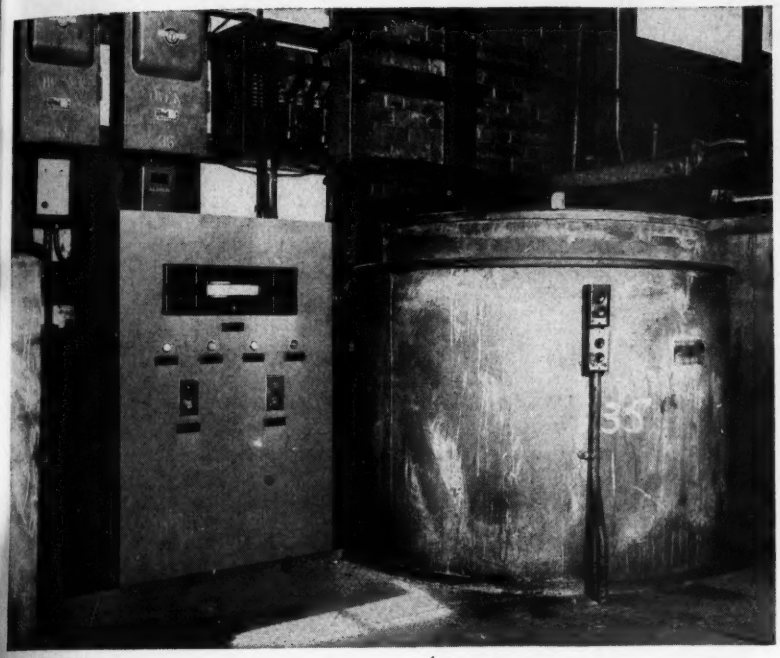
Type 2500-249 Level-Trol

• This improved Fisher Series 2500 Level-Trol is designed to better meet the requirements of field service—to give longer life—ease of maintenance. It still combines proportional range and specific gravity setting in one simple adjustment. Die cast weather—proof pilot case with black enamel finish, and improved lock hasp. Series 2500 Pilot Assembly is interchangeable with Fisher Series 2405 Pilot Assemblies now in service.

FISHER GOVERNOR CO.

MARSHALLTOWN, IOWA

PRECISE TEMPERATURE CONTROL FOR COSTLY HEATING LOADS



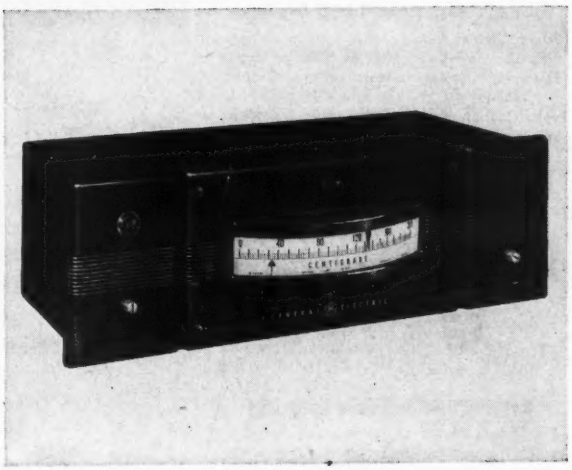
PYROMETER EQUIPMENT

Type HP-3 ON-OFF pyrometer controller being used with a 25-inch air-draw furnace

Expensive loads in industrial heating furnaces are closely controlled with the new General Electric pyrometer equipment. Any change in furnace temperature equivalent to 1/10 of 1 per cent of full scale starts immediate control action when the furnace has come up to temperature. Furthermore, normal changes in humidity, ambient temperature, and voltage do not have a significant effect on the preciseness of control operation.

G-E controlling pyrometers have other features: Micrometer-type setting mechanism allows exact set-point adjustment. Dual set-points of three-position controllers can be fixed independently at any two values throughout the full-scale range. Built-in cold-junction compensation of the thermocouple prevents changes in ambient temperature at the instrument from appreciably affecting performance. And thermocouple-break protection automatically removes the load on a furnace in the event of a break in the thermocouple circuit.

This new equipment is made in indicating, protecting, and two- and three-position control forms. It is available in a variety of standard temperature ranges in the 0–3000 F span. For more details about these process instruments, get in touch with your nearest General Electric representative; or write for Bulletin GEC-713, "G-E Indicating and Controlling Pyrometers." Your local G-E salesman can also tell you about the complete line of thermocouples offered; information will be supplied if you write for Bulletin GEC-714, "G-E Thermocouples, Components, and Accessories." General Electric Co., Schenectady 5, N. Y.



General Electric's pyrometer line consists of flush- and surface-mounted indicators, controllers, and protectors. Shown above is a Type HP-3 two-position indicating controller

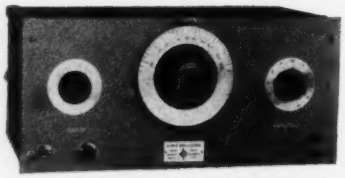
GENERAL ELECTRIC

502-207

Accurate ac test voltages

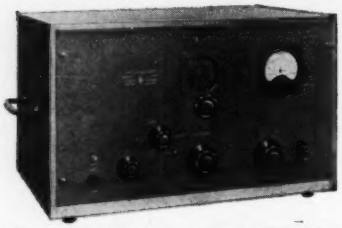
Complete Coverage

½ to 10,000,000 cps



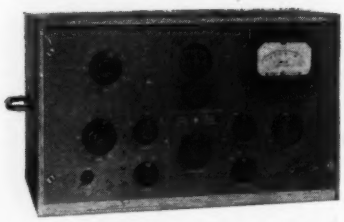
-*hp*- 200 Series Audio Oscillators

Six standard models, –*hp*– 200A and 200B have transformer-coupled output delivering 1 watt into matched load. –*hp*– 200C and 200D have resistance-coupled output and supply constant voltage over wide frequency range. –*hp*– 202D is similar to 200D, with lower frequency range. –*hp*– 200I is a spread-scale oscillator for interpolation or where frequency must be known accurately.



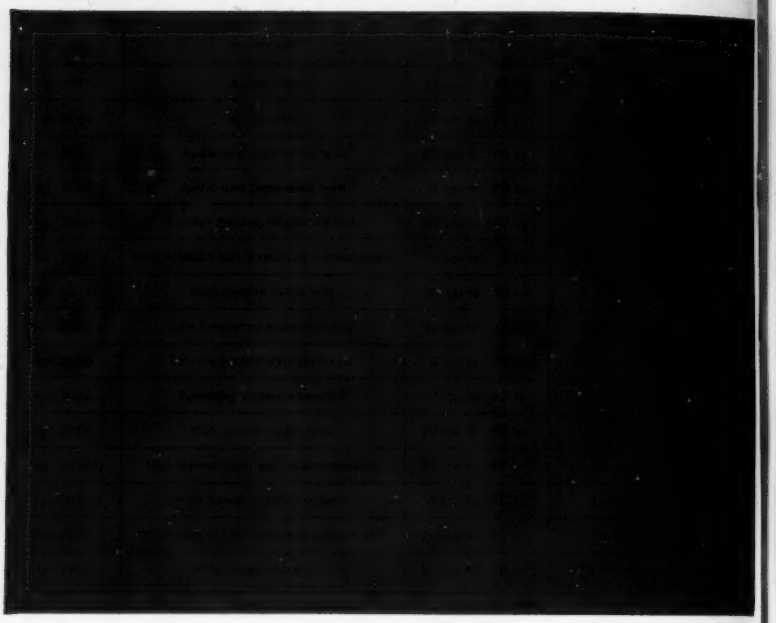
-*hp*- 650A Resistance-Tuned Oscillator

Highly stable, wide band (10 cps to 10 mc), operates independently of line or tube changes, requires no zero setting. Output flat within 1 db. Voltage range 0.00003 to 3 volts. Output impedance 600 ohms or 6 ohms with voltage divider.



-*hp*- 206A Audio Signal Generator

Provides a source of continuously variable audio frequency voltage with less than 0.1% distortion. Very high stability, accuracy 0.2 db at any level. Specially designed for testing high quality audio circuits, checking FM transmitter response and distortion, broadcast studio performance or as a low distortion source for bridge measurements, etc.



Whatever ac test voltage you need—whatever frequency or magnitude you require—there is an -*hp*- oscillator or generator to provide the exact signal desired.

-*hp*- oscillators offer complete coverage, ½ cps to 10,000,000 cps. They are dependable, fast in operation, easy to use. They bring you the traditional -*hp*- characteristics of high stability, constant output, wide frequency range, low distortion, no zero set during operation.

-*hp*- oscillators and audio signal generators are used by manufacturers, broadcasters, sound recorders, research laboratories and scientific facilities throughout the world. For complete details on any -*hp*- instrument, see your -*hp*- sales representative or write direct.

HEWLETT-PACKARD COMPANY

2250 C Page Mill Road **Palo Alto, California, U.S.A.**

Sales representatives in principal areas.

Export: Frazar & Hansen, Ltd., San Francisco, New York, Los Angeles

2250

HEWLETT-PACKARD hp INSTRUMENTS

Custom-made SYLPHON STAINLESS STEEL BELLOWS ASSEMBLIES

WHEREVER YOU USE stainless steel bellows assemblies, in thermostatic devices, pressure controls, hydraulic mechanisms, valves, etc.—you can make savings when we make them for you.

Tick them off! No production problems for you. We take over the complete job. No question about accuracy. We make them to your exact specifications. They're built by skilled personnel—backed by half-a-century of experience in this specialized field.

More savings for you. We have the facilities and the special equipment that means production for you on schedule—in any volume.

You may need a stainless steel (or other metal) assembly that is similar to one we have already produced. Or you may need a special type. Whatever you require, our technical staff will work with you on design and development—see that you get *exactly* what you need.

Find out how you can save in many ways. Write for information. And ask for that gold mine of ideas—Catalog JE-1200.

TEMPERATURE CONTROLS

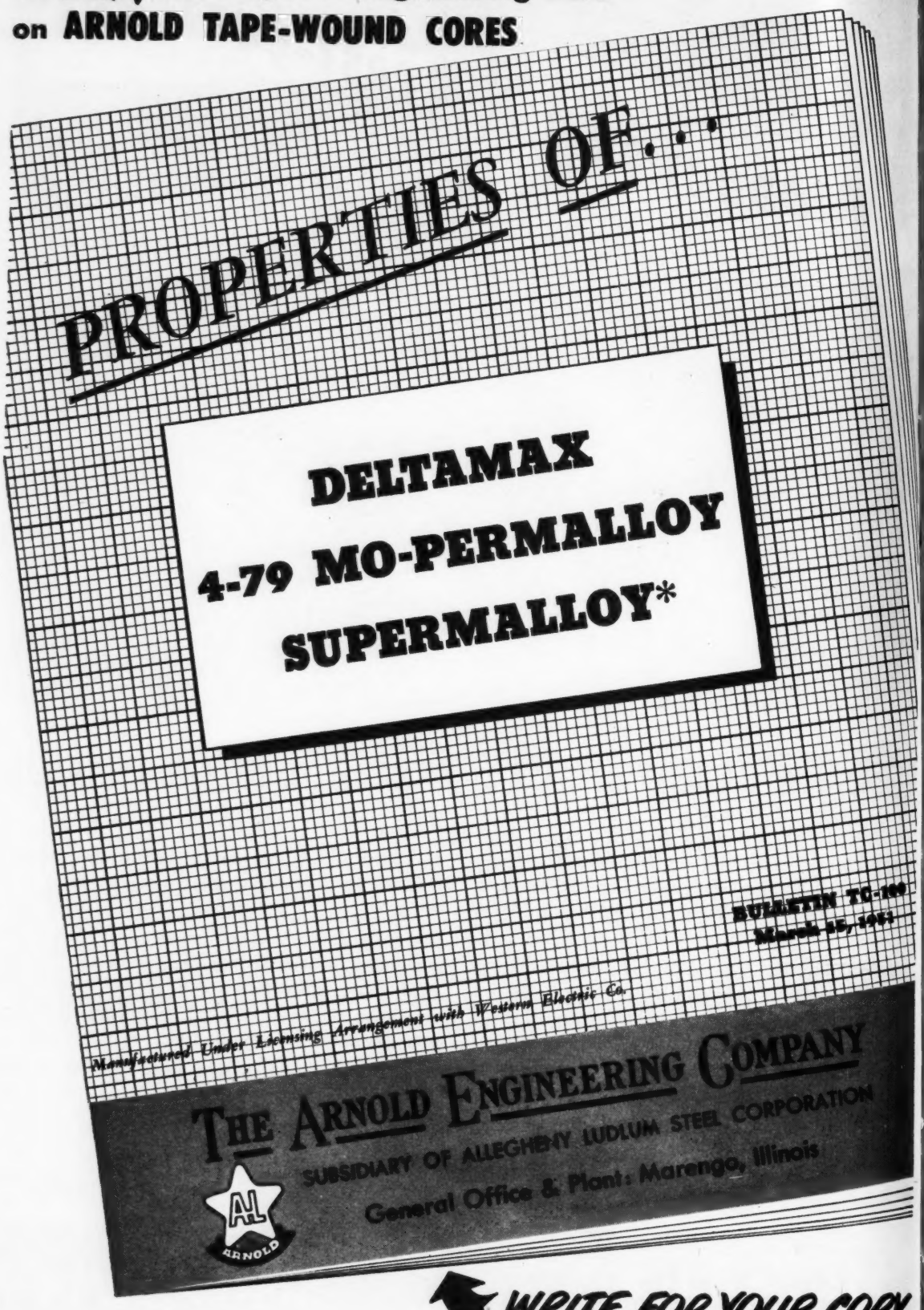
FULTON SYLPHON DIVISION Knoxville 4, Tenn.

Robertshaw-Fulton CONTROLS COMPANY

BELLOWS ASSEMBLIES • BELLOWS DEVICES

BRIDGEPORT THERMOSTAT DIVISION Bridgeport 1, Conn.

NEW! 24 Pages of Engineering Data on ARNOLD TAPE-WOUND CORES



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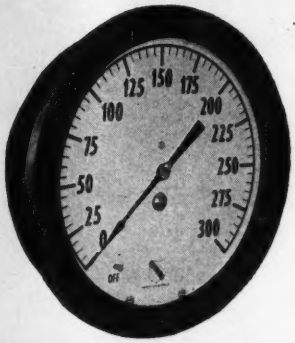
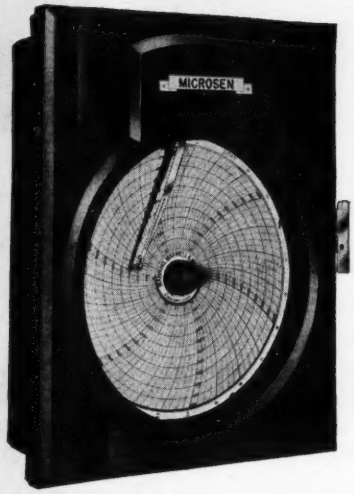




FACTS ABOUT THE NEW *Microsen*

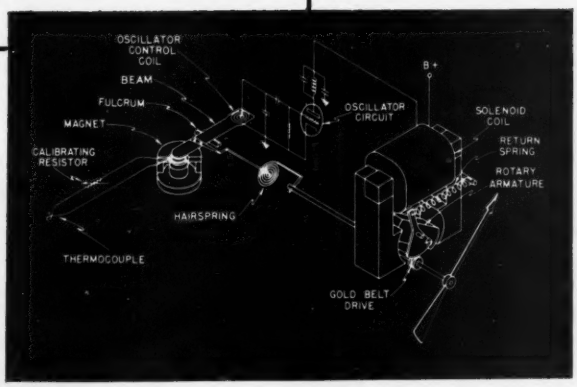
TEMPERATURE MEASURING INSTRUMENTS

Conventional industrial temperature measuring devices, like millivolt pyrometers and potentiometers, are often too fragile, complicated or costly for many applications.

Microsen Temperature Indicators and Recorders have none of these disadvantages, whatever the demands of service. They are rugged, simply constructed, economical – yet measure temperature precisely between –100° and + 3000°F.

Heart of the instrument is the power-actuated Microsen Balance, a unit extremely sensitive to low power input–insensitive to line voltage variations. Both dials and charts are readily calibrated to thermocouple temperature scales. Thermocouple cold junction compensation is achieved–regardless of ambient temperature effects–by a built-in, thermostatically-controlled and insulated heater. A sealed housing protects all measuring elements from dust and corrosive vapors.

The high torque rotary solenoid, which drives the pointer, makes the instrument especially suitable for round dial indication, thus reducing the opportunity for parallax error. It also assures "pin point" accuracy in positioning the pointer, and permits the use of dials as large as 12 inches.



HOW MICROSEN INDICATORS AND RECORDERS MEASURE TEMPERATURE

The Microsen Balance maintains equilibrium between two forces. One is proportional to thermocouple input, the other to the mechanical position of the instrument pointer.

Any change in thermocouple input deflects the Microsen beam and changes the proximity of the beam's flag end to the oscillator coil. The oscillator circuit then detunes and creates a current change through the vacuum tube and solenoid coil.

As the solenoid armature rotates, it positions the pointer so that the hairspring torque is opposed and equal to the input torque. The mechanical indication is thus weighed in exact proportion to thermocouple input. Consequently, the pointer accurately indicates the temperature on the dial.

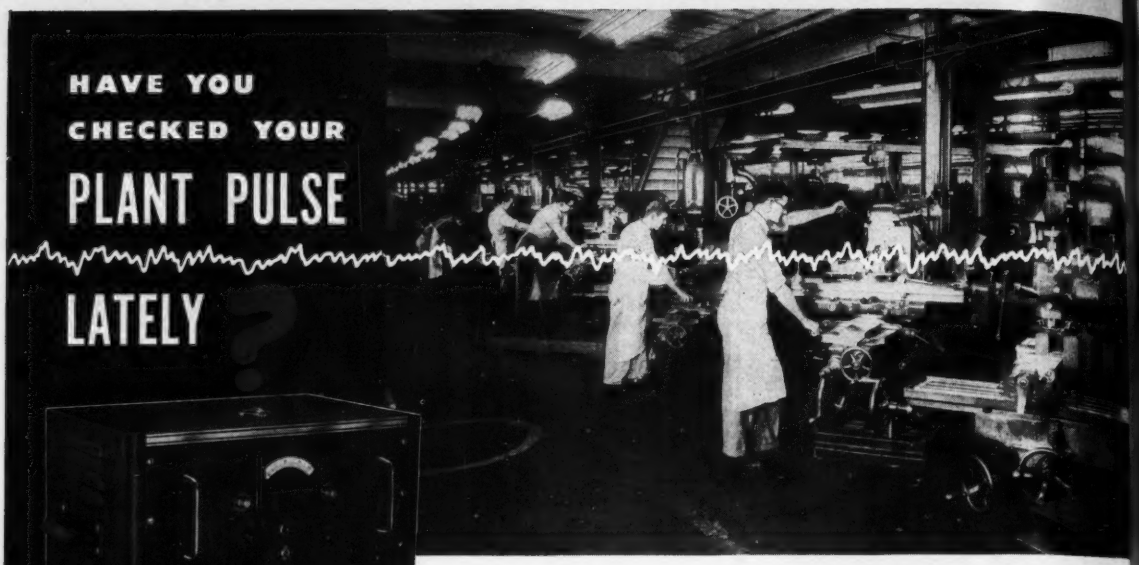
MICROSEN BULLETIN 404 contains details about these revolutionary new temperature measuring instruments. Also included is information about Microsen Electric Indicators and Recorders for other fields of measurement. Write for a copy.

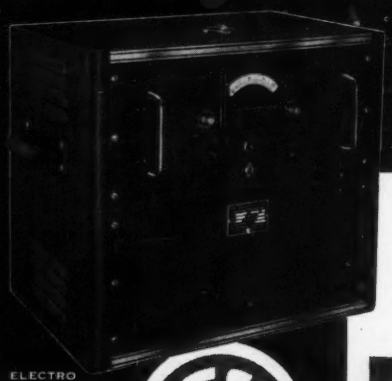
MICROSEN ELECTRICAL INSTRUMENTS

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'MICROSEN' ELECTRICAL AND 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

HAVE YOU
CHECKED YOUR
PLANT PULSE
LATELY





ELECTRO MECHANICAL TYPE EM4115 SHOWN

AUTOMATIC VOLTAGE REGULATION WILL
HELP CURE OPERATING DEFICIENCIES

STABILINE

EM *Automatic* VOLTAGE REGULATORS

feature LOW COST and EFFICIENT OPERATION
IMPROVE PERFORMANCE and REDUCE COSTS

Increased demands on today's electrical manufacturing equipment call for maximum performance, extended parts life and reduced maintenance. When incoming line voltages fluctuate, manufacturing inefficiencies and rising costs are bound to occur. To maintain constant voltage to equipment regardless of variations in line voltage or load current, install a STABILINE Automatic Voltage Regulator type EM (ELECTRO MECHANICAL).

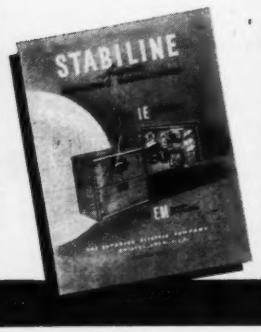
Simple and easy to install, a STABILINE type EM features high efficiency — zero waveform distortion — complete insensitivity to magnitude and power factor of load — adjustable output voltage and no critical adjustments.

	Nom. Output Voltage	Input Voltage Range	Output Voltage Range	Output Current (Amperes)	Output KVA	Type
Single Phase	115	95-135	110-120	17.5	2.0	EM4102
				52.0	6.0	EM4106
				130.0	15.0	EM4115
	230	195-255	220-240	32.5	7.5	EM4207
				120.0	27.5	EM4228
	460	400-520	420-460	15.0	6.6	EM4407
				40.0	17.6	EM4418
Three Phase	230	195-255	220-240	25.0	10.0	EM6210Y
				38.0	15.0	EM6215Y
				50.0	20.0	EM6220Y
				113.0	45.0	EM6245Y
				175.0	70.0	EM6270D
	460	400-520	420-460	16.0	12.5	EM6412Y
				22.0	17.5	EM6417Y
				33.0	25.0	EM6425Y
				66.0	50.0	EM6450Y
				100.0	75.0	EM6475Y
		420-500	420-460	131.0	100.0	EM64100Y

There's a STABILINE type EM to meet your need. Standard types are listed in the rating chart. For special requirements consult The Superior Electric Company, 705 Church St., Bristol, Conn.

STABILINE type IE (INSTANTANEOUS ELECTRONIC), a completely electronic unit with no moving parts, is available in ratings from 0.25 to 5.0 KVA.

Learn more about STABILINES type IE and EM. Write today for Bulletin 5351 complete with application data, ratings, dimensions and circuit diagrams.



THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

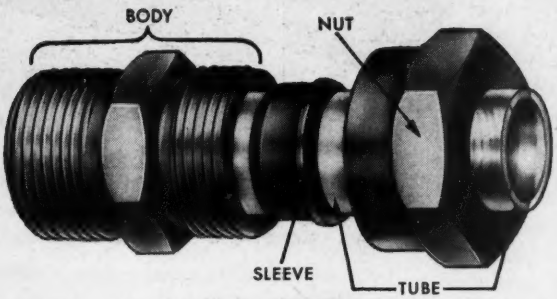
POWERSTAT VARIABLE TRANSFORMERS • VOLTBOX A-C POWER SUPPLIES • STABILINE VOLTAGE REGULATORS

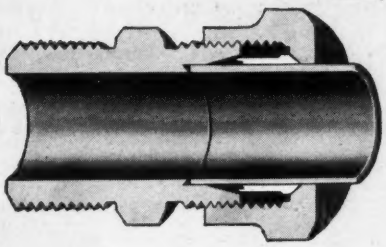
FOR THE ONE MAN IN YOUR ORGANIZATION
TO WHOM **Fittings** ARE **Important**

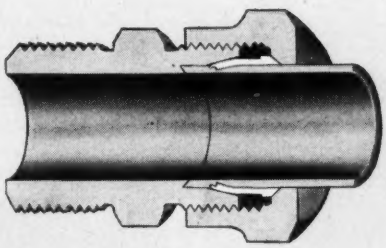
We Developed

"ERMETO®"

Now you can make tube and pipe connections at 1000 psi and above with NO FLARING, NO THREADING, NO WELDING, NO SOLDERING! The patented design of Weatherhead ERMETO Fittings permits installation with no tools but a wrench. Easy to take apart and re-tighten with a pressure tight joint. *Maintenance time saved is production time earned!*







1. Sleeve is heart of Ermeto Fitting. Sleeve and nut slip onto tube; end of tube inserts into body of fitting.

2. Tighten nut; pilot of sleeve contracts engaging outer surface of tube.

3. Fully tightened. Tube end butts tight against body shoulder. Nut presses sleeve bevel causing entire sleeve to clamp tube. Forces acting on sleeve cause it to bow, give it a spring action which holds tension between body and nut—prevents loosening.

You can forget psi when you specify ERMETO. Designed for high-pressure use, ERMETO Fittings have so simplified and cut costs that it pays to standardize on ERMETO FOR ALL JOINTS. The advantages in simplified inventories are obvious. ERMETO meets J. I. C. requirements. Made in sizes ⅛" to 2" O. D. in steel, stainless steel and brass.

WRITE FOR DETAILS—get catalog No. E-1457. Address—The Weatherhead Company, Dept. S, 300 E. 131st Street, Cleveland 8, Ohio.

FIRST IN HYDRAULIC CONNECTIONS

WEATHERHEAD

Plants at Cleveland, Ohio; Angola and Columbia City, Indiana; and St. Thomas, Ontario

The Mark of Quality

Here's How to Erase Smoke Troubles

VIOLATION OF SMOKE ORDINANCE

LOSS OF FUEL ECONOMY

BAD COMMUNITY RELATIONS

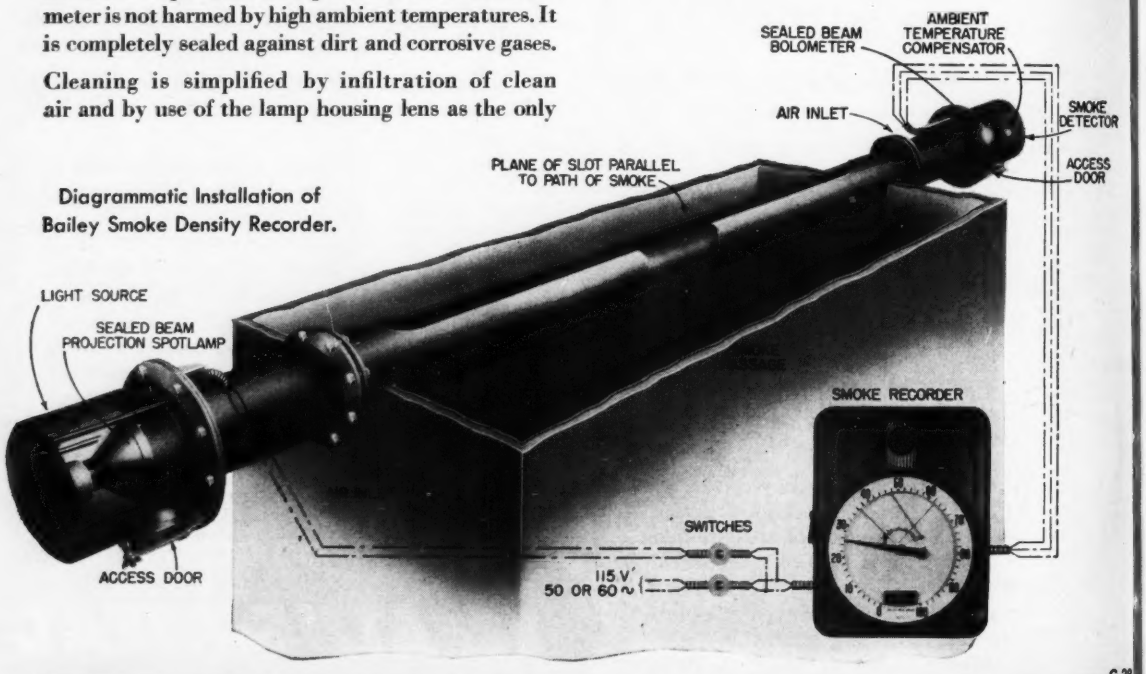
★ One of your first steps in erasing these troubles which result from excessive smoke, should be the installation of a Bailey Smoke Density Recorder. This 24-hour recorder is not an ordinary photo-cell instrument. Instead it detects smoke density by a Bolometer which is simply a sturdy tungsten filament and a parabolic mirror, mounted in a standard sealed beam automobile head lamp housing.

In using this simple, unique smoke detector, you do not have to provide cooling devices since the Bolometer is not harmed by high ambient temperatures. It is completely sealed against dirt and corrosive gases.

Cleaning is simplified by infiltration of clean air and by use of the lamp housing lens as the only window between the Bolometer and the gas passage.

It's easy to secure and maintain alignment of the sealed beam light source with the Bolometer since they are mounted at opposite ends of a slotted pipe which extends across the smoke passage.

For complete information on how you can profitably use this unique instrument to erase your smoke troubles, ask for Bulletin 211, "Bailey Smoke Density Recorder".



Diagrammatic Installation of Bailey Smoke Density Recorder.

G-29

BAILEY METER COMPANY

1041 IVANHOE ROAD, CLEVELAND 10, OHIO • BRANCH OFFICES IN PRINCIPAL CITIES

BAILEY METER COMPANY LIMITED, MONTREAL, CANADA

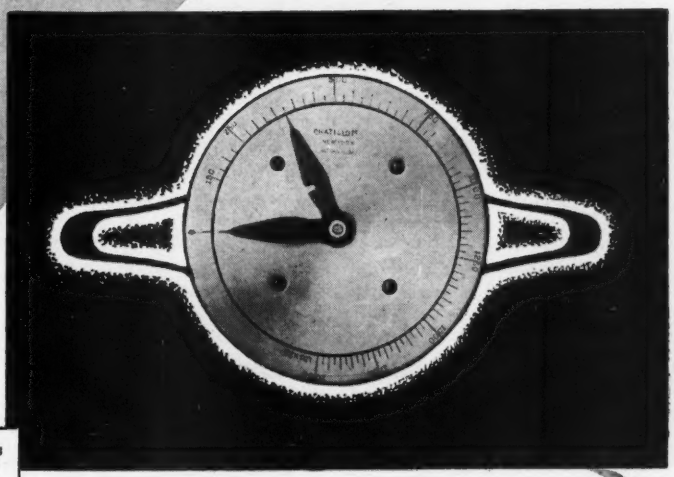
Let Bailey Smoke Density Recorders Watch Your Stacks

WHEN THE PRESSURE OF INDUSTRY IS GREAT...COUNT ON CHATILLON FOR UNFAILING AID!

Since 1835, John Chatillon & Sons have been world famous for the precision manufacture of force measuring devices which meet the most specific requirements of industry.

CHATILLON TRACTION DYNAMOMETERS

- For determining sag in stringing transmission lines.
- To ascertain force required to pull underground cables and wires through conduits.
- For guy wire tensions, pole, insulator and anchor strength.
- For use in conjunction with apparatus that apply force to test strength of materials and structures.
- Gear Mechanism is Enclosed in Dustproof housing.
- Accuracy is Guaranteed to within 2% plus or minus of dial reading.



Traction Dynamometers are made in Capacities shown below:

Capacity & Graduations in lbs.	First Dial Reading lbs.	Dial Dia. Inches	Shipping Weight lbs
1000 x 10	100	7	8
2000 x 25	150	7	9
5000 x 50	250	8	9
10000 x 100	500	10	15
25000 x 200	600	14	45
50000 x 250	1000	16	56
100000 x 500	1000	18	95

Larger Capacities to Order

FILL IN AND MAIL COUPON TODAY

John Chatillon & Sons, 85 Cliff Street, New York 7, N. Y.

Gentlemen: Please send me complete brochures on

☐ Traction Dynamometers ☐ Push Pull Gauges
☐ Laboratory Scales ☐ Force Measuring Devices

Name.....Company.....

Address.....Position Held.....

JOHN CHATILLON & SONS

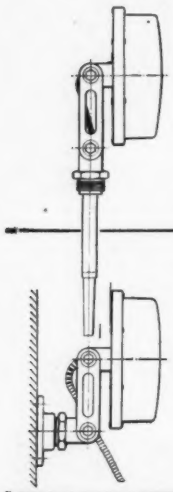
85 CLIFF STREET, DEPT. I-4, NEW YORK 7, N. Y.

Manufacturers of Precision Instruments Since 1835

PALMER

mercury actuated Dial Thermometers

now in three types to suit any requirements

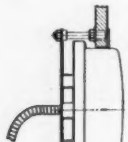


1 Rigid Stem Dial Thermometer

Rigid stem tapered bulb, interchangeable with standard industrial thermometer separable socket.

2 Wall Mounted Dial Thermometer

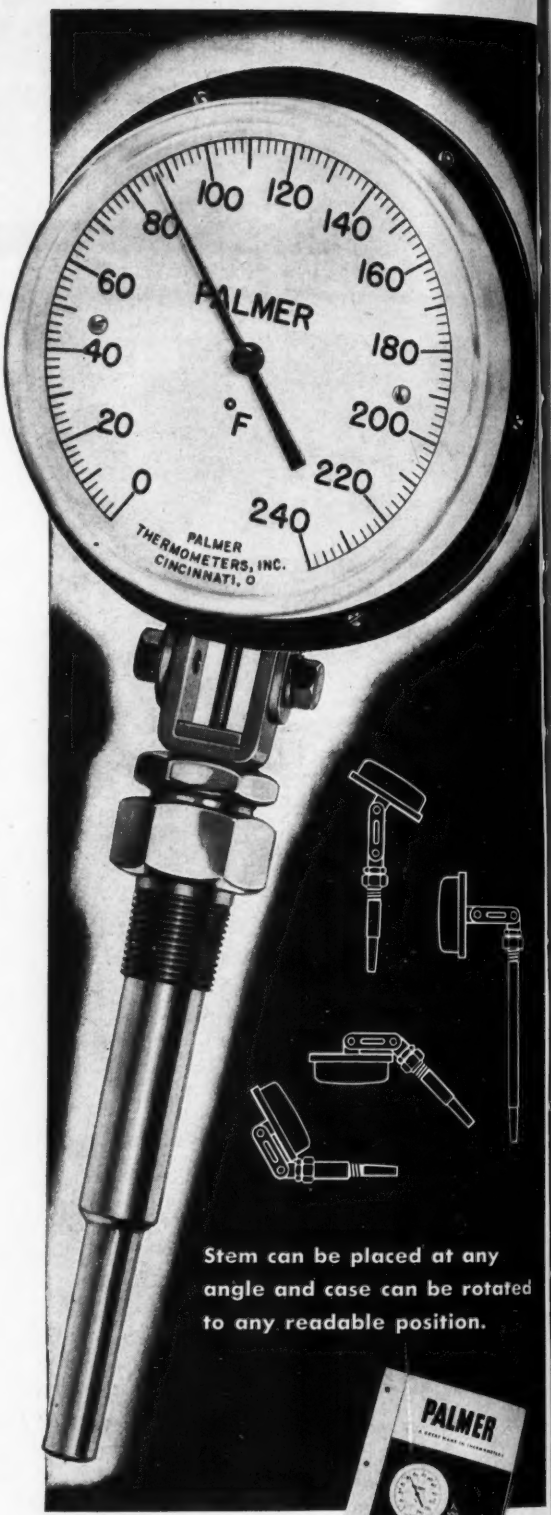
Wall mounted dial thermometer with flexible connecting armor. Case adjustable to easy reading position.



3 Flush Mounted Dial Thermometer

Flush mounted style for panel mounting with flexible connecting armor.

All three types have a full 4½" dial Face



Stem can be placed at any angle and case can be rotated to any readable position.

for accuracy: Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for angularity: Can be adjusted to most readable position at any angle desired.

for readability: Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

for interchangeability: Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

SEND FOR THIS BULLETIN

For details on the New Palmer Dial Thermometer, please write for Palmer Bulletin 51-129.

PALMER THERMOMETERS, INC.

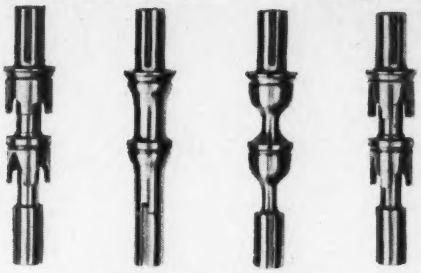
Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2511 NORWOOD AVE., CINCINNATI 12, O.

* COMPARE

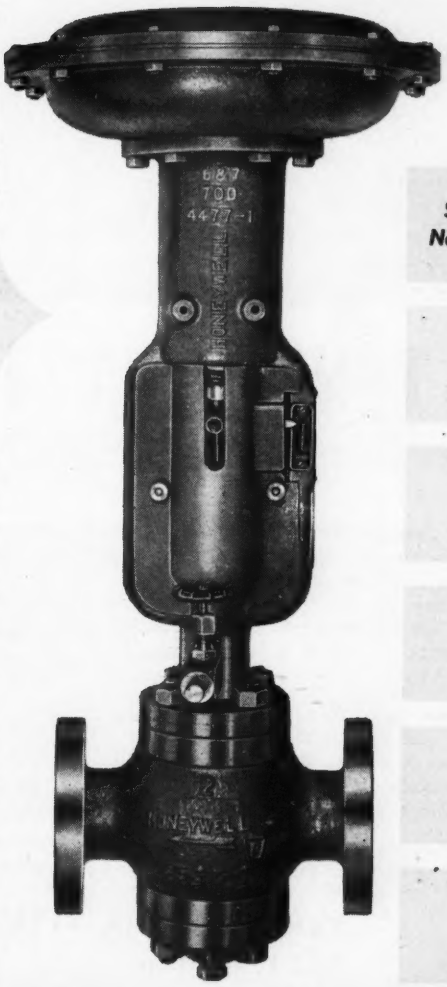
THIS FEATURE

OF THE HONEYWELL "SERIES 700" VALVE



VARIETY OF DISCS

A wide variety of discs to meet the most exacting process requirements. Included are V-port and contoured discs in either linear or percentage styles, as well as flat discs for on-off service. All discs are ground and polished . . . all seating surfaces are lapped to assure tight fitting.



Specially Designed Neoprene Diaphragm

Duplex Upper Stem Guide

One-Piece Bonnet

Packless Bellows Seal

Safety Stem Lubricator

Reversibility in the Field

* Compare the selection of discs available with this valve with that of any other wide band proportional type. Look at them closely . . . see how they permit you to select the disc which meets *your* specific requirements.

Then check the other features of the valve . . . the Specially Designed Diaphragm, the Duplex Stem Guide, the One-Piece Bonnet, the Packless Bellows Seal, the Safety Stem Lubricator, the easy reversibility in the field.

Your comparison will prove that the Honeywell Series 700 has *all* of the features you look for in a fine valve.

It's available in a wide range of styles and sizes. For detailed information, write for a copy of Catalog 700-2, or call in your local Honeywell engineer . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 1908 Windrim Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

New Bulletin 750, "Control Valve Sizing Data," is now available

MINNEAPOLIS **Honeywell**

VALVE PRODUCTS

IT'S TINY BUT IT'S TOUGH!

PENFLEX BUILDS BIG PROTECTION IN SMALL SIZE, FOR CAPILLARIES

Tough, small and flexible, this metallic tubing, only ⅛" I.D., was developed primarily as protection for the fine capillary tubes in industrial recording instruments. New uses every day are found for this remarkable flexible protection—as shielding for conductors in thermocouples, oscilloscopes, and in many electronic applications.

Gas-tight and water-tight, with instant flexibility to conform easily to difficult layouts, this Penflex 4-wall interlocked metallic hose, in brass, steel or alloys, provides ideal shielding in radar and television applications or in any low-loss transmission problem.

That's Penflex "Flexineering" (the science of engineering each type of flexible tubing to the problem): instrument makers needed a tubing that would conform easily, yet provide tough, sure armor for delicate capillary tubes. Penflex gives just such protection: the 4-wall interlocking construction assures competent strength, resistance to corrosion and high temperatures, and an easy flexibility.

Penflex builds flexible metallic tubing from 5/32" I.D. to ½" I.D. in galvanized, bronze, stainless-steel and Monel metal. For quick solutions to problems on leakproof, flexible shielding for capillaries or conductors in the instrument field, Penflex has the answer. For engineering service and a complete line of metallic hose and tubing it's Penflex.

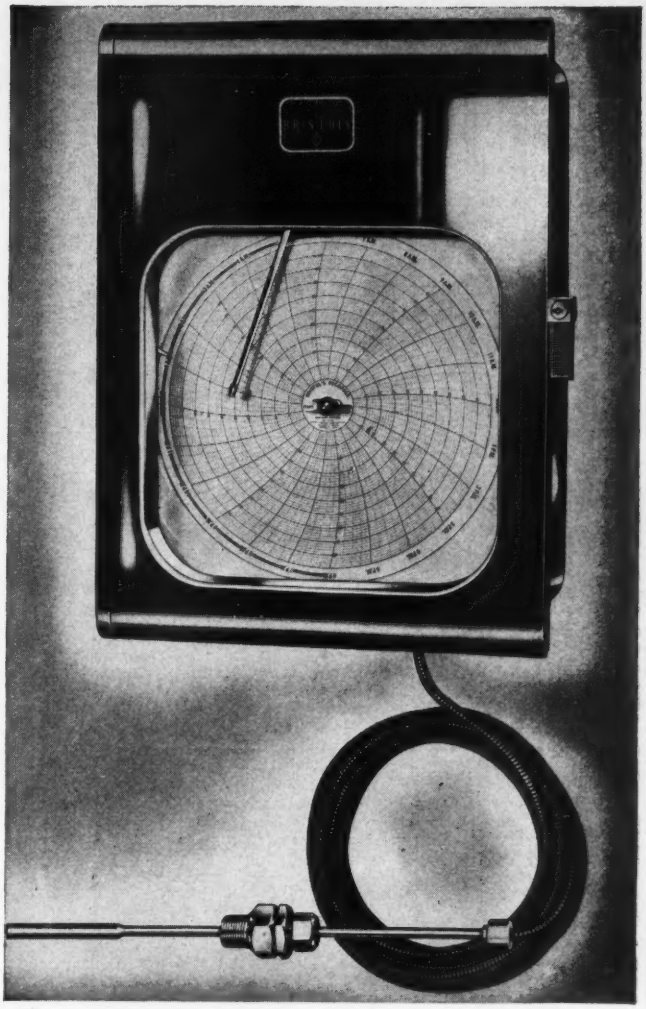
PENNSYLVANIA FLEXIBLE METALLIC TUBING CO.

7212 Powers Lane **Philadelphia 42, Pa.**

Branch Sales Offices—BOSTON • NEW YORK • CLEVELAND • CHICAGO • HOUSTON • LOS ANGELES

Penflex... HEART OF INDUSTRY'S LIFE LINES

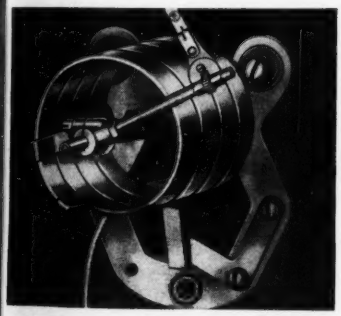
NEW SERIES 500 RECORDING THERMOMETER CARRIES ON THE BRISTOL TRADITION



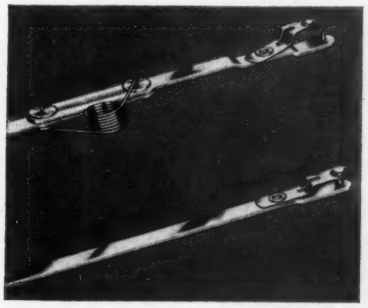
The Bristol Series 500 Recording Thermometer for temperatures between minus 125 F and 1000 F incorporates every modern improvement for dependable accuracy, ease of use and convenient servicing.

In addition, it represents all the wealth of thermometer "know-how" gained by nearly 60 years of experience in building hundreds of thousands of recording thermometers—known all over the world for their high accuracy and dependability.

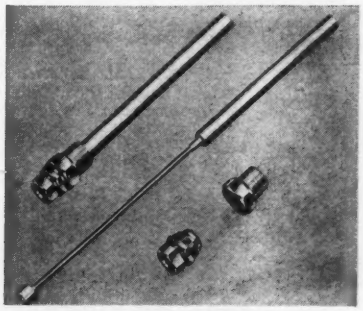
Send for the new Thermometer Catalog T840. Address THE BRISTOL COMPANY, 113 Bristol Road, Waterbury 20, Conn.



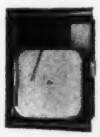
MORE SECURELY SEALED—TROUBLE-FREE—The measuring system is securely sealed against leakage. Parts are joined with silver solder by induction heating.



STURDY, FRICTION-FREE CONNECTION between measuring element and pen arm mechanism is provided by strong, adjustable links with polished stainless steel pins.



FLEXIBLE ARMOR is interlock-type, withstands heaviest abuse. *Bulbs*—plain, union or socket type—easily converted.

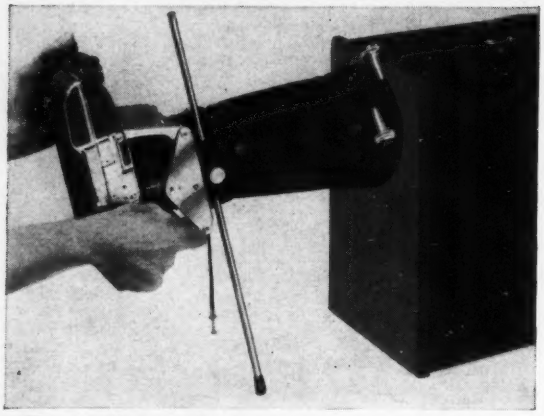


THE DEPENDABLE GUIDEPOST OF INDUSTRY

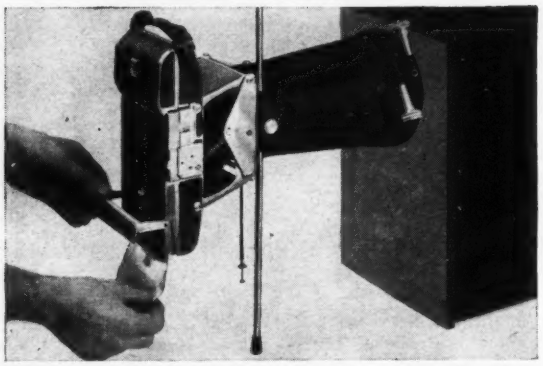
BRISTOL

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

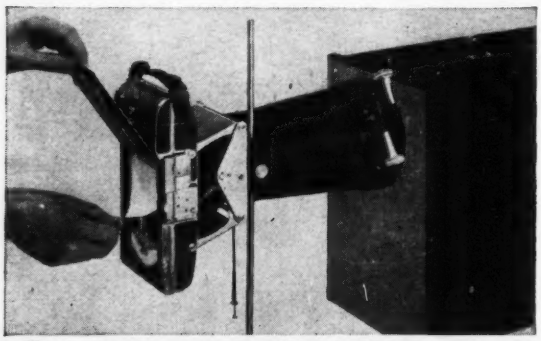
How to make Oscillograms FAST!



Set up the camera. The Fairchild-Polaroid camera consists of three units: adapter ring, hood, and camera body. To set it up, you place the handy adapter ring over the oscilloscope bezel, slip the hood into the ring, then snap the camera into the bayonet lock on the hood. That supporting rod is a safety feature that protects both camera and oscilloscope.



Pull the tab to finish exposed print. After a snap of the shutter, the exposure is made and you're ready to finish the print. If you want two exposures, it's easy to move the camera body down and make a second exposure. To finish the print, you merely pull tab at back of camera.



Remove the finished print. A minute after you've pulled the tab, the finished print is ready for evaluation. Just open the camera back and there it is. An easy job, but you have a photographically accurate record of the trace in less time than you could sketch it from memory.

—SET UP THE CAMERA
—SNAP THE SHUTTER
—SEE THE PRINT

ALL IN 3 MINUTES—or even less
with the Fairchild-Polaroid® Oscilloscope Camera

The easiest way is the fastest way when you're photographing oscilloscope images with the Fairchild-Polaroid® Oscilloscope Camera.

No more darkroom processing! With this new camera it takes only two minutes (less if you're fast) to set up and snap the picture, one minute to finish a print. Each 3¼ x 4¼ print records traces exactly one-half life size to make comparisons easy.

Write for complete data and prices on F-284 Oscilloscope Camera Kit including camera, carrying case, and film. *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N. Y.* Dept. 120-14F1.

SPECIFICATIONS

LENS—Special 75 mm. f/2.8 Wollensak Oscillo-anastigmat.

SHUTTER—Wollensak Alphax; speeds 1/25 sec. to 1/100 sec., "time," and "bulb."

FOCUS—Fixed (approx. 8 in.)

PICTURE SIZE—3¼ x 4¼ in. (2 or more images per print; 16 exposures per roll of film.)

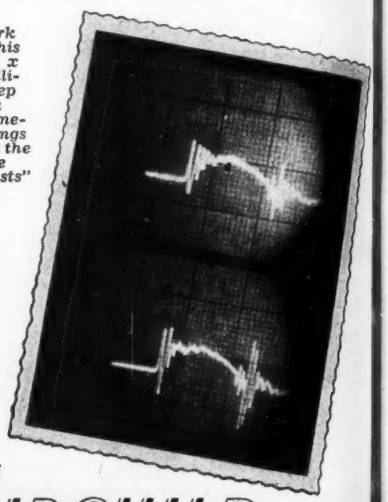
IMAGE SIZE—One-half reduction of scope image.

WRITING SPEED—to 1 in/μsec at only 3000V accelerating potential; higher speeds at higher voltages.

DIMENSIONS—Camera, 10½ x 5¼ x 6¼ in.; hood, 11 in. length, 7½ in. dia.; adapter, 2 in. width, 6⅝ in. max. dia.

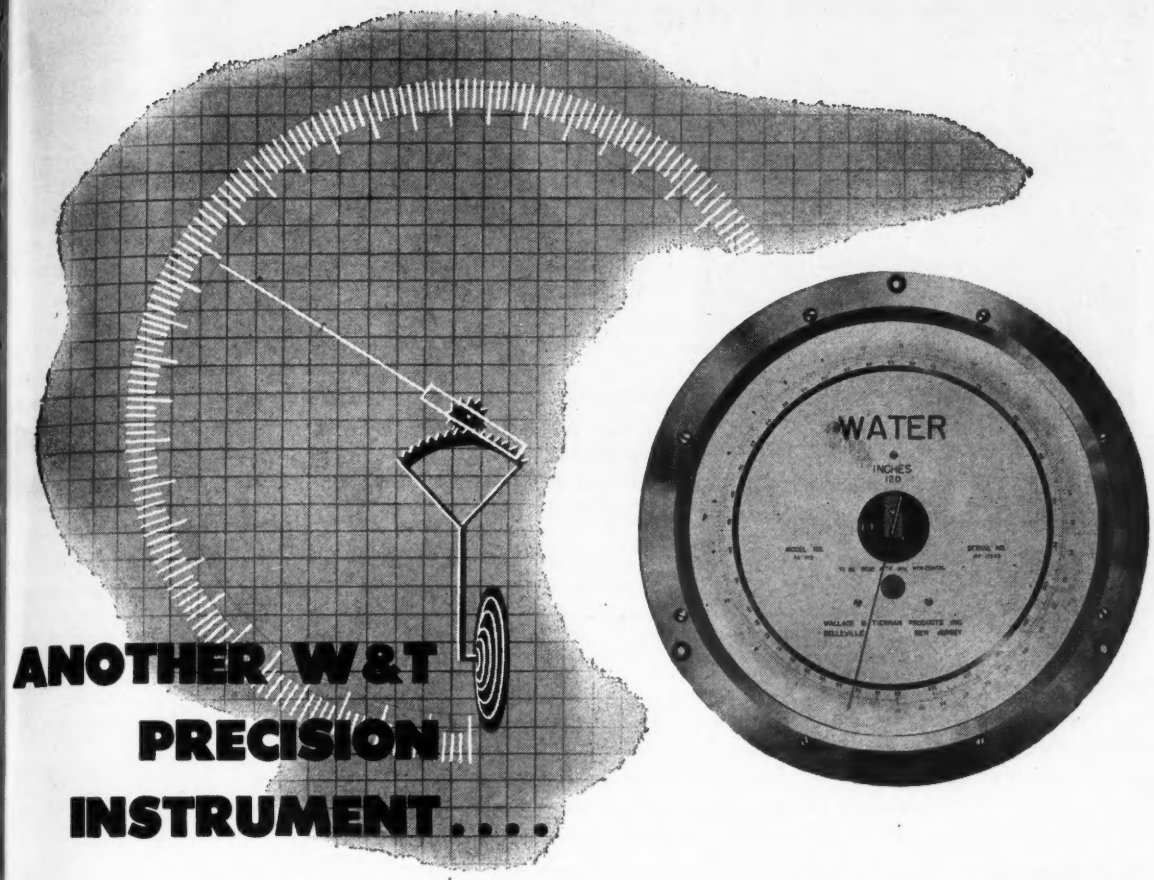
WEIGHT—Complete, 7¾ lb.

Typical of the work being done with this camera is this 3¼ x 4¼ print of 35-millisecond single-sweep transient—one of a series of accelerometer-output recordings that made possible the completion of nine recorded "drop-tests" in 40 minutes.



FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

A-79



ANOTHER W&T PRECISION INSTRUMENT....

The W & T Precision Dial Manometer

The W&T Precision Dial Manometer answers the problem of conveniently measuring pressure with a sensitivity of 1 part in 10,000.

This sturdy, compact instrument, which is widely used for wind tunnel work, power plant test stands and in gas turbine testing, has a large easy-to-read dial. It is custom calibrated in *any* pressure units over various ranges up to a maximum of 200 inches of mercury.

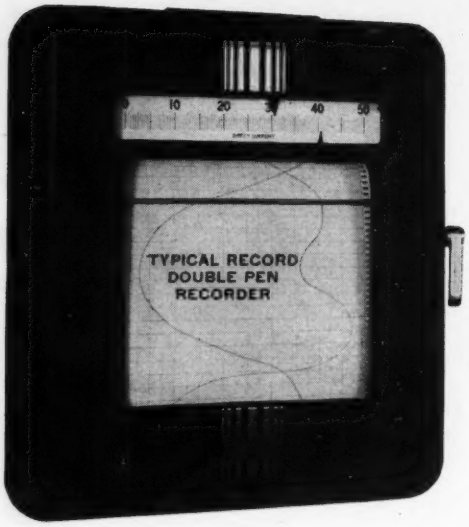
In addition, the W&T Precision Dial Manometer possesses these outstanding advantages:

Accuracy .....1 part in 1000
Scale length.....45"
Case .....pressure tight, metal for flush mounting.
Full protection against over pressure.
Measures gauge pressure, vacuum and differential pressure.

This instrument with its sensitive response and precision results is typical of a wide variety of pressure instruments of all types — from low pressure indicators to altimeters — manufactured by W&T. If you have a problem in pressure measurement, write, telling us the details. We'll be glad to help.

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

Four new Speedomax Recorders to plot lab data automatically



To save the researcher from tedious curve plotting, here are 4 new Speedomax Recorders. There's a double-pen recorder to put two continuous curves on one chart . . . there's a recorder for "X-Y" curves . . . there's an adjustable range—adjustable zero recorder for narrow ranges at high levels . . . and there's a recorder for photomultiplier tubes.

These instruments are standard production models, rugged, built . . . yet remarkably sensitive. Electronic amplification makes Speedomax fast; null-balance measurement insures accuracy. High motor torque keeps response rapid even when auxiliary devices add to shaft load. Pens move across $9\frac{7}{8}$" scale in 1, 2, or 3 seconds as desired. Thorough shielding and filtering keep out normal stray fields.

Available extras include chart tear-off; sliding window for writing on chart with door locked; fluorescent light; various signalling and shut-off devices, etc.

DOUBLE-PEN RECORDER

is used to compare two related functions when variables change too fast for a two-point recorder. Saving valuable panel space, it plots two continuous curves on the same chart—either "overlapping" or "side-by-side." Any standard range can apply to either pen. Available chart speeds are from 1" to 1800" an hour.

X-Y RECORDER

plots any two variables convertible to d-c signals. X corresponds to pen travel; Y to up-and-down chart movement. Instrument can plot vacuum tube characteristics, stress-strain curves, temperature-temperature difference curves, etc. Chart moves 10" in only four seconds.

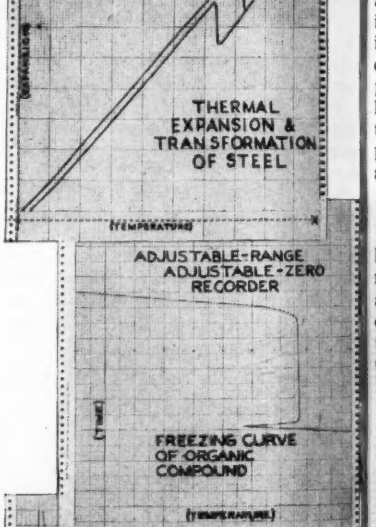
ADJUSTABLE RANGE and ADJUSTABLE ZERO

make this recorder applicable to a wide variety of test measurements. It's used with load cells in strain gage applications; it's used in expanding small changes at various temperature levels; it's used in studying speed changes over narrow bands, etc. Range is -2 to $+20$ mv maximum; -0.1 to $+1$ mv minimum. Zero suppression is -50 to $+50$ mv.

PHOTOMULTIPLIER TUBE RECORDER

for recording light and other low-level radiation. With high-gain amplifier built in, recorder connects directly to current leads from photomultiplier tubes. Lowest range (0 to 0.02 microampere) is consistent with smallest currents. By flicking a switch, higher ranges can be selected. Thus varying intensity spectra are recorded in detail.

If you have a specific problem, we'll be glad to recommend the standard or special Recorder to handle the situation. Address our nearest office, or 4955 Stenton Ave., Phila. 44, Pa.


X-Y RECORDER
THERMAL EXPANSION & TRANSFORMATION OF STEEL
ADJUSTABLE-RANGE ADJUSTABLE-ZERO RECORDER
FREEZING CURVE OF ORGANIC COMPOUND
PHOTOMULTIPLIER TUBE RECORDER
SPECTRUM OF LIGHT FROM A MAZDA LAMP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad EM9(2)

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

The Function *of the* Engineering Publication

AN engineering publication has two main functions. The first is to affect liaison between various types of workers. When a man is working in a technical field, the activities, problems, and developments of all the other workers in that field are of interest and importance to the man. Whether he is scientist, engineer, maintenance man, application man, salesman, manufacturer, or user, his existence is affected by the work of all the others. The engineering publication makes it possible for each type of worker to keep in touch with the others. If a man is to grow in his field, it is his responsibility to use this important medium.

The second main function is to teach the principles, applications, and problems of the field. These problems are technical, political, social, and financial. The technical problems are physical and engineering. The political problems involve such matters as taxes and tariffs. The social problems include recognition and recompense. The financial problems often have to do with high-level decisions by management. The technical publication is the market place where the problems are looked at, priced, and considered.

A Serious Problem

A serious problem that has been brought to the attention of the instrument industry is the development of a critical shortage of college-trained engineers. The Engineering Manpower Commission of the Engineers Joint Counsel, in a release dated April 18, 1951, says:

"Our country is in great need of engineers. More than 30,000 of them must be graduated from the engineering schools each year to staff the national effort to out-design, out-develop, out-produce and out-perform a potential enemy who outnumbers us greatly. This is a conservative estimate. But in order to achieve it, engineering schools will have to more than double their present enrollment for years to come.

"Since the 'mortality' rate in engineering schools is about 50 percent, an annual freshman enrollment of 60,000—double the number that entered engineering schools this year, would be required to produce 30,000 engineering graduates a year. The question is: How can twice as many high school graduates be attracted to engineering schools?

"The situation is further aggravated by the expectation that high school graduations will have declined 10 percent by 1958.

"Since all engineering classes graduating up to 1954 are already enrolled, the number of graduates up to that year may be estimated. If no students are withdrawn from the schools by Selective Service, there will still be an accumulated shortage of 40,000 engineers by 1954. This is the most optimistic estimate possible.

"The number of engineering graduates in 1954 will be down to about 17,000. Unfounded rumors that the engineering field was oversupplied pushed the 1950 enrollment down to about 30,000, which is below that of 1940. The fact is that industry has already absorbed the last two record-breaking graduations of nearly 50,000 each, and is hotly contending for the 30,000 that will be graduated in 1951.

"The record classes of the last two years were brought about by the unprecedented number of veterans who enrolled under the G.I. Bill of Rights in 1945-46. Since then enrollment has fallen off rapidly."

Instrumentation Will Help

Henry F. Dever, president of Brown Instruments Division of Minneapolis-Honeywell Regulator Company, declared in an address before the Scientific Apparatus Makers Association:

"Special emphasis must be placed on engineering manpower which is highly important to the scientific instruments field. I'm sure I need not belabor the point of the present scarcity of engineers, young or old, but the end is apparently not in sight. Some of the technical societies, as well as the educators of the country, lay before us an extremely grave picture.

"The history of our past national emergencies has shown that the place of instruments in the production of all kinds of goods, both miltary and civilian, is one of high essentiality and that industry needs these products in many instances to supplement or increase efficiency of their own manpower, not only in production but in research and scientific areas.

"The key to the progress of America's engineering and manufacturing organizations has long been their aggressive interest in adopting improved manufacturing methods, based upon exhaustive analysis of new machines and new techniques as they are developed."

A Possible Solution?

Another serious consequence of the decrease in college enrollment is a weakening of the already-shaky financial structure of many privately endowed colleges. Unless something is done, the number of students will continue to decrease, the number of colleges will also decrease, and this vicious circle will end either in a weakening of the country or in government control of colleges.

A partial solution might be found in granting more scholarships. As the colleges cannot afford many more, industry and finance might supply many more scholarships to worthy students.

A more fundamental solution might be to make it possible for college students to work their way through college. The college might have student-run factories or services which are adapted to the hours that students can work. These ventures might be privately financed legitimate businesses—paying taxes and union wages. In this way neither business nor labor-union interests could object to their existence. Further, no young man then could feel he was deprived of a college education because of the expense of that education.

—M. Aronson

As our many friends know, the serious illness of our Editor, Major M. F. Behar, has delayed publication of the *Handbook of Measurement and Control*. We know you will be glad to hear that Major Behar is recovering, and that Chapters 1, 2, 3, 4, 5, 7, and 16 of the *Handbook* are at the printer. The other Chapters will go to the printer shortly. We want to thank all of you who are awaiting the Handbook for your patience. IT WON'T BE LONG NOW. Thanks again.

Methods *for* Sorting Mixed Metals

By ANTONY DOSCHEK, Pittsburgh, Pennsylvania

AT ONE TIME or another, most of us have been entertained and intrigued by the stage magician who produced a given card from a folded pack by means of a mystical gesture, or divined the writing on a covered slate, or, with the touch of a magic wand, foretold the geneology of a spiritous liquid contained in an opaque vessel. Those of us who have worked with methods for sorting mixed metals envy the magician his confidence and the certainty of his results but, even though we know his methods are devised by clever trickery we try to rival him in utter seriousness by methods which, to many, may appear to be no less magical than are his.

Our mystic passes are made with coils and our magic wands are standard samples or spectrographic electrodes. Our props and trappings are galvanometers, bridge circuits, oscillators and amplifiers. And our line of patter is oftentimes just as confusing as is the magician's. To be quite frank, we inventors and devisors of instruments for sorting mixed metals will even agree that a bit of discreet legerdemain at exactly the right time has a remarkably diminishing effect on "borderline" results.

Be that as it may, however, this article will try to outline the methods and instrumentations which have been applied to mixed-metals sorting problems as well as a few methods which have been devised and tested experimentally but have not as yet found their way into commercially available embodiments.

The class of testing methods which are of chief interest here are those which produce a definitive result by rapid, non-destructive or virtually non-destructive means. Such methods are achieved by the measurement of the physical properties of metals and are to be distinguished from the "wet" methods of the chemical analyst. Furthermore, we are mainly interested in those sorting methods and instruments which, because of their rapidity and simplicity of application, are useful in plant operations; even though they leave something to be desired academically in the choice of the physical phenomena used to define a particular variable.

Experimental proof almost always justifies academic sanction: though an obtained value is known to be in error, from an absolute point of view, it is a useful value if it can be reproduced under the same circumstances. More often than not, the usefullness of a packaged method lies in the ruggedness of its construction and its inherent reproducibility rather than in its sensitivity or absolute accuracy.

Moreover, the methods and instruments which are discussed herewith are primarily sorting tools whose main applications are to problems that can be discriminated on a "go- no go" basis. When used as tools to expedite the sorting of the occasional—but eventual—mixup or as production control equipments, they can be relied upon to discriminate against unwanted conditions only after a somewhat thorough study of their behaviour has been made through measurements, not only of "acceptable" and "unacceptable" representative standards, but also of standards which lie between, and outside of, the extremes of the problem.

The investigation of those borderline conditions, which R. R. Webster of the Jones & Laughlin Research Laboratory so aptly terms the "shades of gray," is most important in ascertaining the instrumental meaning of "black and white." It is only through the evaluation of the shades of gray that the simple "go- no go" test can be raised to the status of an accurate and powerful measuring method, regardless of the inventive ingenuity or the quality of engineering which is incorporated within the instrument itself. This, of course, places a goodly portion of the responsibility for the success and usefulness of a sorting instrument directly upon the shoulders of the user.

By far the largest group of packaged sorting instruments employ one or more phenomena of magnetics as a basic operating principle. Development and perfection of ideas and equipment in the field of magnetic sorting has been stimulated by the absolute non-destructiveness and the mechanical simplicity with which a magnetic test can be made, as well as advanced understanding of magnetic phenomena gleaned from companion fields of technology.

Aside from magnetic flaw detection and inspection equipments, magnetic sorting devices divide themselves into two general and, to a certain extent, overlapping classes: the comparators and the magnetic analyzers. The terms "comparator" and "analyzer" are used herein to distinguish between two basic forms of magnetic sorting means and are not meant to relate to trade names, as such.

Comparators are designed, in many cases, around the fundamental circuit of magnetic test equipment: the inductance bridge, a form of which is shown in Fig. 1. Its method of use involves placing a specimen representing a standard or desired metallurgical condition into one of two coils in the bridge circuit while the unknown specimen is placed into the other of the two coils. Assuming that the bridge is balanced with no specimen in either coil, then a balance indication can exist only when the test piece is similar or identical to the standard specimen.

The order of similarity which can be detected is, of course, determined by the intrinsic sensitivity of the bridge circuit design, the shape factor and ampere turns of each coil and the alternating frequency of the bridge excitation current. Since we can not be concerned with the theory and principles of bridge circuits here, we refer to the voluminous literature in electrical engineering texts and make special mention of the lucid treatment of many forms of bridge circuits, useful in magnetic gaging, in Howard C. Robert's "Mechanical Measurements by Electrical Methods." We are concerned, however, with what takes place when a magnetic sorting test is in progress and especially with the meaning of the meter indication as related to the nature of the similarity of the unknown and the standard specimens.

All inductance bridge measurements are influenced by the basic magnetic properties of the material which is being tested. These properties, which consist of permeability, reluctance, retentivity, hysteresis, coercivity and others, act in aggregate to compose the indication of the bridge circuit meter. Added to the magnetic variables are the complex electrical parameters of the bridge as well as those of the indicating circuit itself.

All of these together compose a part of the magnetic measurement to show that a simple indication of a few divisions on a meter scale is actually a most amazingly complex integration. And yet, certain properties of magnetic materials, mainly permeability, have such a strong individual influence that they can be relied upon to relate definitely to a given metallurgical condition. Steels varying in carbon can be most readily sorted by magnetic methods, although other alloying elements also influence the magnetic state when combined in steel.

The applications of the inductance bridge are generally confined to the sorting of moderately small parts of very uniform shape and size, and of such form that they can be positioned accurately within the magnetic fields of the test coils. Certain other inherent characteristics of the inductance bridge, however, make its use for general sorting in the metals plant somewhat limited.

The range and adaptability of the simple comparator is extended when the search coil is divorced electrically from the coil carrying the exciting current. This forms the essential difference between the comparator and the magnetic analyzer. Fig. 2 shows a diagram of a simplified circuit of the analyzer type. The particular and practical ad-

Paper presented at the Conference "Instrumentation for the Iron and Steel Industry," sponsored by the Carnegie Institute of Technology and the Pittsburgh Section, Instrument Society of America, March 28 and 29, 1951, Hotel Roosevelt, Pittsburgh, Penna.

vantages of this type of circuitry arise from the fact that an equal order of sensitivity at all settings of the standard voltage can be achieved and that a very desirable degree of linearity of meter deflection with change of magnetic properties, principally permeability, can be attained. This is not the case in the inductance bridge, which can be extremely sensitive at null balance and relatively insensitive when off balance.

From the practical standpoint, the analyzer form of sorting equipment enables the operator to visualize the relative groupings of test pieces having similar magnetic properties. Instrument controls for sensitivity selection are provided so that, for a given lot of mixed pieces, a number of groupings will be indicated on the meter at an optimum sensitivity setting without having to resort to a process of changing standards in order to define each group. Several magnetic analyzer circuits incorporate a means for varying the frequency of the excitation current because it has been found that all magnetic differences are not easily definable at any one given frequency: thus the inherent latitude of the variable frequency magnetic sorting equipment is greatly enhanced.

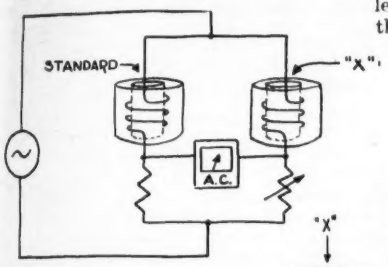


FIG. 1

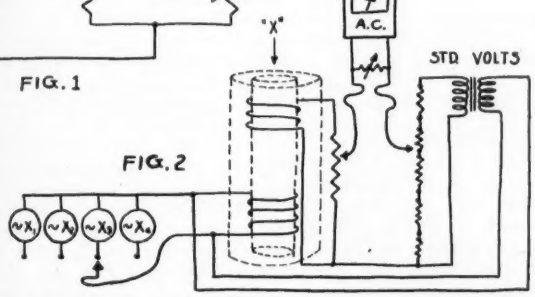


FIG. 2

A third basic form of magnetic test equipment is found in the high-frequency sorting devices which employ the core loss properties of metals to produce indications of similarity and dissimilarity. These indications are particularly effective when projected by a cathode-ray tube since subtle metallurgical differences can be shown by virtue of their effect on wave form and phase angle. To the eye of a trained observer, these graphic picturizations are indicative of specific metallurgical variables.

Equipments embodying the aforementioned magnetic principles are offered by several manufacturers. Magnetic Analysis Corporation are specialists in the field. They and the General Electric Company both make comparators and analyzers and are prepared to furnish test data representing many years of field application. The newest of these equipments is offered by the Fisher Scientific Company in cooperation with a Jones & Laughlin Research Laboratory development. The instrument, the Steelsorter, is to be commended because of its simplicity of operation and its particularly hardy design. The J. W. Dice Company and the Non-Destructive Testing Corporation, Limited, offer high-frequency cathode-ray analyzers.

Magnetic sorting methods are seemingly the most magical ones since nothing, apparently, touches the pieces under test and yet a subtle metallurgical or physical variation can produce a startling effect on the instrument indication. At times, a variation of this type is of no practical interest to the user of the equipment and this leads to a feeling of uncertainty with the equipment in particular or even toward condemnation of the magnetic test as a whole. Nevertheless, it should be remembered that the magnetic test measures all of the magnetic properties of the test piece simultaneously and that these properties are directly related to mass and contour as well as the magnetic characteristics of the alloy as imparted to it by its chemical composition and its metallurgical constitution.

The fact that a measurement may be made at all by the simple expedient of inserting a test piece into a coil form, or holding a search coil against the test piece, should be sufficient incentive to the user to seek advice and means to overcome certain anomolous readings which arise from the so called immaterial variables of the test piece. Ways and means to ignore the effects of "unwanted" variations are generally incorporated within the instrument design and are part of the operating instructions (seldom studied by the *actual* operator of the equipment in the plant) and techniques can often be devised to accomodate the particular conditions of a difficult sorting problem.

Two examples of such techniques follow: magnetic sorting of tubing products will be affected unfavorably by eccentricity of the tubing bore even though the amount of eccentricity is tolerable from the inspection or quality control viewpoint. Test comparison for this condition can be arranged by supporting the tubing on a longitudinal axis which is slightly out of coincidence with the longitudinal axis of the search coil.

While supported in this manner within the search coil, rotation of a perfectly concentric tube should produce no change in instrument indication whereas rotation of a tube having similar dimensions and metallurgical properties, but with a bore which is eccentric with respect to its outer periphery, should produce an instrument indication which varies from a minimum to a maximum value: the mean value of this variation is most representative of the magnetic property of the tube as a whole and should agree with the value obtained on a concentric tube if the chemistry and the constitution of the two are identical: Fig. 3.

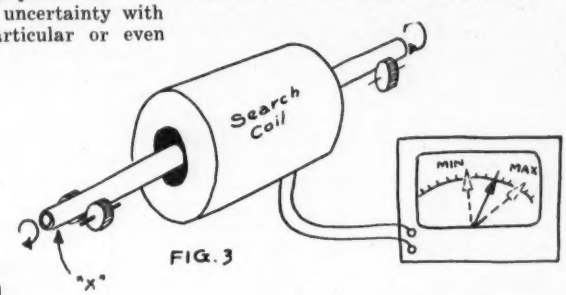


FIG. 3

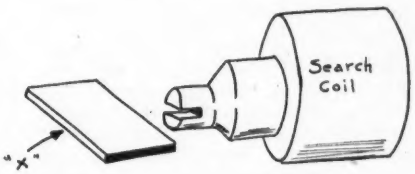


FIG. 4

Much can also be accomplished to enhance the versatility of standard magnetic sorting equipment by designing pole pieces or coil cores suitable for adapting to special problems. For example, the edge of a sheet or strip can be inserted into a protruding pole piece which has been slotted to allow strip insertion to a fixed depth (Fig. 4). A change in the reluctance of the gap formed by the slot, due to a change in the magnetic properties of the inserted edge, will be evidenced by the instrument indication.

A new and unusual form of magnetic sorter has been developed and will be announced in the very near future (Fig. 5). This device, for which no trade name has as yet been selected, will be a low-cost pocket version sorter —smaller than the familiar optical pyrometer. A large number of turns are wound around a coil form surrounding a high flux density permanent magnet. The wound magnet is mechanically spring loaded and held by a trigger within a sliding arrangement so that its end may be held in restraint a fixed distance from the test piece.

The test is made by releasing the

trigger, which causes the magnet to come into contact with the test piece at a fixed velocity during each test. This causes a unidirectional current surge or a voltage pulse to appear across the terminals of the coil. The voltage pulse is fed into a calibrated voltage divider and thence to the grid circuit of a cold cathode gas tube which incorporates a small neon glow lamp in its plate circuit. The device is calibrated previously to each sorting problem by adjusting the voltage divider so that one of the two metallurgical conditions lights the glow lamp while the other fails to light it.

This action comes about as the result of the differences of permeability, mainly, of the two conditions—the greater the permeability of the test piece, the larger will be the magnitude of the voltage induced in the coil. Prior to each test, the plate circuit of the cold cathode tube is opened automatically, thereby extinguishing the glow lamp in readiness for the following test. The equipment is completely powered by a hearing-aid type battery which is said to have a useful life of over 5,000 tests.

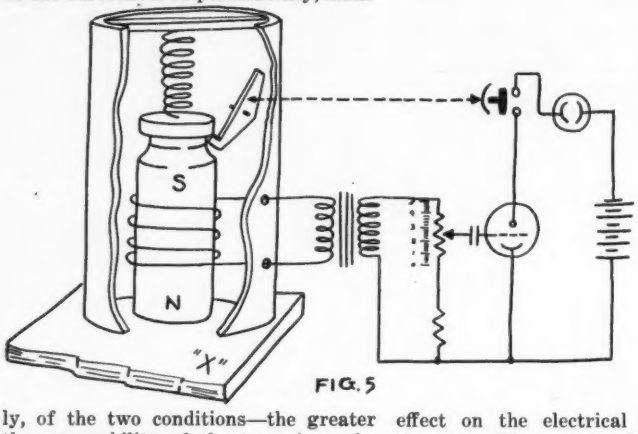


FIG. 5

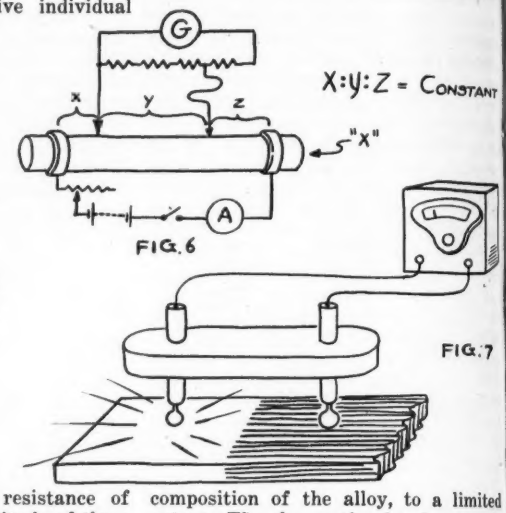


FIG. 6

FIG. 7

It may be well to summarize the best applications of magnetic testing here before proceeding with a few methods which do not make use of magnetic measurements.

First: Most metals or alloys, whether or not ferromagnetic, lend themselves to sorting by magnetic methods. Low excitation frequencies, from 15 cps. to about 2,000 cps., being indicated for the ferromagnetic types while the non-ferromagnetic types can be sorted at higher excitation frequencies; up to about 200 kilocycles per second.

Second: Magnetic methods adapt themselves best to sorting straight pieces of uniform cross-section although, by use of special techniques, irregular or asymmetrical shapes can be sorted successfully.

Third: The magnetic test is absolutely non-destructive and is extremely well suited, by virtue of its rapidity and mechanical simplicity, for adaptation to continuous production control or inspection.

The determination of the chemical compositions of metals and alloys by a measurement of their specific electrical resistance is an old art. Every known element has a value of specific electrical resistance which is, to a greater or lesser degree, different from every other one and it is possible to identify the commonly used alloying elements in steel on this basis when they are in their pure state. In most engineering metals, however, the component elements do not exist in the pure state alone. The high-temperature chemistry of the melt-down produces extra-elemental compounds and phases—solid solutions, carbides, oxides, metastable compounds, and so forth.

All together contribute a qualitative as well as a quantitative individual effect on the electrical resistance of the mass. The great multitude of these additive effects of actually indeterminate values makes the identification of an alloy, as regards its specific chemical composition, virtually impossible by a single determination of its specific electrical resistance. On the other hand, through the aid of some foreknowledge relative to the possible grade of the alloy, a hardness test and one or two rapid spot tests, it is possible to apply resistance measurements effectively to sorting problems.

Where it can be demonstrated that the electrical resistance of two test pieces is sufficiently different to allow positive discrimination between the two, the main difficulty is the achievement of uniformly reproducible contacts of the micro-ohmmeter energizing current to the test pieces. This is especially difficult by reason of the fact that large currents must be used and passed through a reasonably short length of the test piece and the average useful length may have an electrical resistance of the order of, perhaps, a few millionths of an ohm: the resistance of one contact alone can be many times this value unless carefully engineered designs are used. A simplified circuit for the measurement of low resistances is shown by Fig. 6.

Nevertheless, G. R. Greenslade and his associates at the Flannery Bolt Company Laboratory, have developed a low-resistance measuring instrument which is called the Electell Fracture Detector. Although this instrument is intended primarily for the detection and measurement of incipient and developed cracks in railroad car axles and crank pins, its basic engineering design and construction is so fine that mention of the equipment must be made here with the hope that it will be investigated by those who are interested in applying electrical resistance methods to composition sorting problems.

One further possibility for the mill application of electrical resistance measurements suggests itself here. It has been observed in the laboratory that mill scale on hot-rolled products varies in its electrical resistance as the composition of the alloy, to a limited extent. The observation has been made by means of the simple instrumentation shown in Fig. 7. A small area of the test piece is cleaned free of scale and one terminal of Weston Model 1 Direct Reading Ohmmeter (0.0 to 2.5 ohms full scale) is attached to it. At a fixed distance from the clean surface contacting probe, the other ohmmeter terminal probe is held against a scaled portion under fixed load. Both probes are provided with spherical tips approximately 3/16 inches in diameter; made of hard bronze.

The orders of magnitude experienced during determinations of scale resistances range from several hundreths of one ohm to as high as two ohms—in one case it was possible to sort X4130 from SAE 1645 by this method when, for some reason, all other methods which had been tried failed to do the job. Variations in mill scale composition and thickness are related to the base material as well as to the particular thermal history to which the material in question had been subjected at some time previous to the mixup and this fact alone may deserve investigation by those interested in quality control methods.

During the early years of the last war, a sorting instrument, called the Identometer, was developed. This equipment employs the thermoelectric properties of alloys to identify mixed metals. Thermoelectric phenomena have been employed for many years in pyrometry and the theory is well known to members of the metals industry.

To recapitulate, however, the theory

states that two chemically dissimilar metals in physical and electrical contact with each other at a point which is either heated or cooled to a temperature other than that of the remainder of the metals will develop an electrical current flow. This current is dependent in magnitude and polarity upon the chemical nature of the dissimilarity and the differences in temperature between the point of mutual contact and the points of electrical contact to the measuring circuit.

In practice, the Identometer instrument is provided with mechanical clamps and spring-clip connectors so that a standard sample of known composition could be connected in the form of an "X" in contact about midway with a test piece (Fig. 8). Two of the four arms of the "X" arrangement were used to connect to the terminals of a high-current density transformer and the other two are connected to a measuring circuit using a low-resistance galvanometer as its indicating instrument.

In the latest form of the Identometer, switching and electronic controls are provided so that a current of 300 to 1,500 amperes flows through the junction point for a period of 0.2 to 5.0 seconds, dependent upon preselection. This causes a small spot weld to form between the standard and the test piece which becomes the hot junction of the thermocouple so formed. The emf. of the thermocouple is indicated on a galvanometer scale immediately after the welding current is switched off.

The thermoelectric test was found to be extremely sensitive to the chemical composition of the alloys and less sensitive to their constitution; exactly the reverse of the magnetic test. A difference of two or three points of carbon, sulphur or columbium was easily detected in fully annealed steels and the presence of nickel, chromium, molybdenum or aluminum caused very pronounced differences in both the magnitude as well as the polarity of the thermocouple electromotive force. By virtue of the gross presence of these elements, all grades of austenitic stainless steels are sorted and identified very readily.

As mentioned beforehand, the magnitude and polarity of the thermoelectric current is determined by the chemical and constitutional nature of the samples as well as the temperature differences between the hot junction and the cold junctions. If we were to plot a curve of the thermoelectric test as made by the Identometer instrument or, better still, replace the galvanometer with a high-speed recorder, we would see that the slope of the curve is determined by the cross-sectional mass of the samples mainly, by reason of the fact that the hot junction is highly localized and very small in size and the duration of the energizing temperature very brief.

That is to say, the electromotive force producing temperature gradient persists longer in samples of light cross-section than it does in samples of heavy cross-section. This effect gives rise to an occasional thermoelectric anomaly—ordinarily, two alloys of identical composition will produce no thermoelectric current but, if one of the alloys is in the form of a heavy rod while the other is a thin wire, a thermoelectric current will be noted due to the relatively rapid dissipation of the temperature gradient in the sample having the greater mass cooling effect. The phenomenon is not significant in a practical sense with samples of approximately equal mass or cross-section.

However, a second effect not ordinarily observed in thermoelectric pyrometry is found to be quite informative. This effect relates to the reversal of the polarity of the thermoelectromotive force with increase in temperature. It can be demonstrated with many thermocouple alloys that emf. progresses increasingly as the temperature is raised up to a temperature at which it takes a maximum amplitude (Fig. 9). Beyond this temperature, the emf. decreases rapidly, as a rule, and, if the thermocouple materials do not begin to volatalize beforehand, will even reach zero and begin to increase again—but toward the opposite polarity. This phenomenon has been noted particularly in work with the austenitic stainless steels, permitting separations of close analyses to be made with ease.

The effective application of the thermoelectric test, nevertheless, has certain drawbacks which should be considered here. In order to produce sufficient exciting temperature at the hot junction, heavy currents must be used. This involves descaling and cleaning the surfaces of the test pieces and providing adequate contact area at the power input ends of the "X" formation as well as at all other points of electrical contact. The intense localized heat generated at the hot junction generally produces a "hard spot" on the work as well as a possible source of fracture when the work is placed into service. Although the test is very well suited to detecting changes in composition, it, nevertheless, does react to effects of constitution and previous thermal and work history. These must be considered when the thermoelectric test is applied to sorting mill products.

Various other forms of the thermoelectric test have been tried with moderate success, the simplest one being a version of an electric soldering copper connected in series with a galvanometer and the work. When the heated soldering copper is held in contact with the test piece, a thermoelectric current will, of course, flow but the reproducibility of the emf. will be found to be difficult to maintain. Holding the temperature of the soldering copper to a small variation around a given value is not difficult when heating is done in air but becomes another matter altogether when contact is made with the test piece.

Not only is the area of the contact extremely critical but the pressure of the contact, the penetration effect, the surface condition of the test piece, the presence of uncompensated, stray thermoelectric currents and the degree and type of oxidation of the soldering copper tip will be found to be major functions of the total current. On the other hand, this simple and convenient low cost embodiment of the thermoelectric test can be used with accuracy and assurance, but to a limited extent, if the soldering copper is provided with a standard sample such that the desirable analyses in the mixed lot produce deflections of the galvanometer indicator toward one polarity while the unwanted analyses give deflections toward the opposite polarity.

The same statements apply to a third form of thermoelectric tester which it is believed will be of interest here because of its somewhat unacademic instrumentation. Inspired by many gun-whipping sorties with imaginary In-

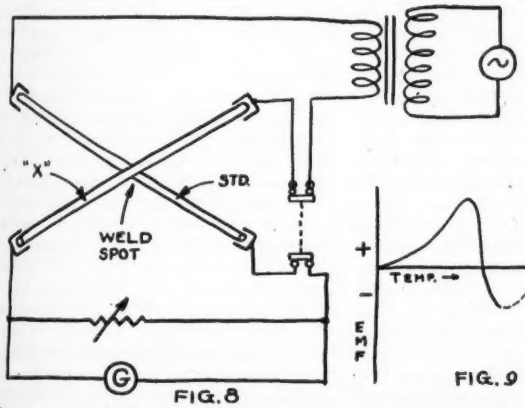


FIG. 8

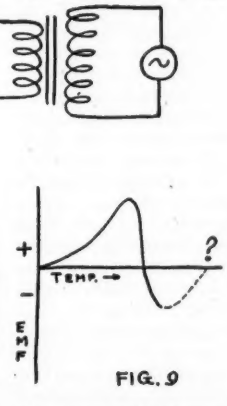


FIG. 9

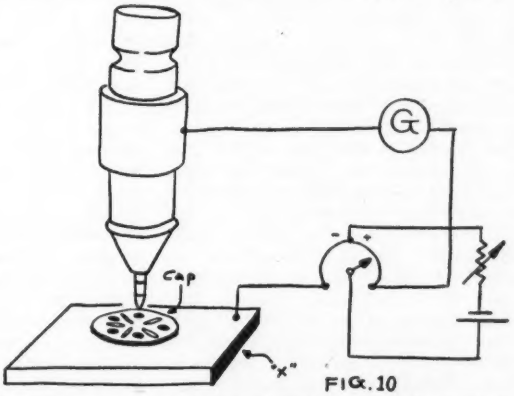


FIG. 10

dians in the company of the author's small son, this simple thermoelectric testing device was found to have certain meritorious and interesting properties. Its instrumentation consists of a center-zero, ballistic type galvanometer, a microvolt bias circuit, connecting leads, an automatic center-punch and a box of top pistol caps: Kilgore #108 Disk Caps preferably. One terminal of the galvanometer is connected through the microbias to the center-punch: the other to the test piece, Fig. 10.

A pinpoint perforation is made through the approximate center of the powder charge of the cap and the cap is placed into position on the work so the tip of the center-punch protrudes through the perforation and makes electrical contact with the test piece. The galvanometer will then indicate any stray thermoelectromotive currents which may be present and these can be balanced out by adjustment of the microbias so that the galvanometer reads zero current flow. Now, if the center-punch is depressed, the toy pistol cap will explode and the intense, localized heat so produced, even though brief, will be found to be quite adequate for the sorting of a great many analyses of alloys. It is not difficult to picture this method embodied in a small, pistol-like device equipped with an automatic roll-cap feeder and electrically connected to a simple and rugged type of ballistic galvanometer. Such a device could be made battery powered and easily portable.

Before proceeding to other methods of sorting, it may be of interest to note here that thermoelectric effects of sufficient amplitude for sorting purposes, can be derived "on the spot," so to speak, during several types of fabricating and machining operations. Considerable work has been done with the thermoelectric measurements of cutting tool temperatures during lathe and milling machine operations but, for the accuracy wanted, it was necessary to devise rather massive dialectric tool posts and holders so as to obtain the required strength along with insulating properties. This is not always necessary for sorting purposes because of the very high temperatures produced by the cutting tools while in operation. It can be shown that, in many instances, residual currents remaining in spite of the shunting effects of large machine components, are sufficient to define the possibility that the operator may have a piece of the wrong analysis in the machine. The same can be said for drill press work and even punching and cold drawing operations.

It seems that industrial processing is replete with by-product phenomena which we usually ignore or fail to recognize but which, with a bit of standardization, a bit of instrumentation and a bit of calibration, can be made to serve some useful and beneficial purpose.

About five years ago, a sorting instrument was developed which indicates chemical and constitutional differences in metals by measuring the electrical currents produced when dissimilar metals are rubbed against one another. The phenomenon is termed the triboelectric effect and its practical embodiment is the Metalsorter instrument. The device is a relatively small, portable tester composed of a control cabinet and difference indicating instrument and a sorting head. The sorting head is provided with a mechanical arrangement to make contact with a test piece and a means for introducing standard specimens into a reciprocating chuck. When the "nose" of the head is held in contact with the test piece and the test-initiating button pressed, the standard specimen reciprocates in contact with the test piece through a fixed number of strokes. The indicating instrument shows the polarity and magnitude of the resultant triboelectric current if the standard and the test piece are chemically or constitutionally dissimilar (Fig. 11).

The chief advantage of the triboelectric test lies in its ability to sort material as to composition or constitution regardless of the size or physical form of the material, within a very large range of limits. Given a six-inch billet, for example, of chemically and constitutionally identical alloy with that of a one-eighth inch rod, the two will produce equal triboelectric indications with a standard test rod. Other advantages lie in its ability to sort any clean, scale free material that can be touched with the standard specimen—the magic wand idea—even though the material is in physical or electrical contact with entirely dissimilar metals.

The triboelectric test is confined entirely to the surface of the test piece. Its reaction is to the surface chemistry and the surface constitution of the test piece and the standard specimen. From this viewpoint, therefore, it is a strange fact that the physical condition of the surface of the test piece, that is, whether it is ground, sand-blasted or cold-rolled, has very little effect on the reading obtained between two given analyses.

This curious non-conformity to expectancy may be due to the specific conditions of the triboelectric test as made by the Metalsorter instrument in that a small diameter rod is caused to reciprocate longitudinally and rapidly across a rounded portion of the test piece: the area of actual contact is about 0.0008 square inches and the loading of the reference specimen about 1.1 pounds; resulting in a contact pressure of about 1,250 pounds per square inch, which may act as a common denominator to burnish rough surfaces and scour smooth surfaces to a certain degree of uniformity.

The exact nature or the fundamental mechanism of the triboelectric effect is not understood. A small portion of the effect is believed to be thermoelectric, in that some heat is generated during the process of rubbing—perhaps a very high instantaneous value as far as the very surface grains are concerned. But discreet experiments show that the thermoelectric contribution to the total triboelectric reading obtained with any two given analyses, regardless of their intrinsic thermal conductivity, represents only about 12 percent.

The Metalsorter instrument is capable of sorting all types of metals and alloys—as well as some non-metals—but its sensitivity to constituent differences in the series of austenitic stainless steels is far less than to any other series of alloys. This fact alone serves to divorce the triboelectric effect from the commonly assumed first cousin status of the thermoelectric effect.

The simple mechanics required to produce a triboelectric effect would indicate its suitability to the inspection and control of continuous rolling processes (Fig. 12). A stationary contacting feeler of known analysis held under spring pressure against a moving section of wire stock during a cold drawing process, for example, could be calibrated to indicate a change in composition which may have resulted from butt-welding wire billets of dissimilar composition to make up the required length of coil.

Since the triboelectric effect reacts to change in work-hardness, also, the same scheme could be applied to measure the degree of surface hardness or cold reduction imparted during a rolling pass by simply providing two contacting reference specimens of identical composition and electrically connected in series opposition; one at the feeding side of the roll and the other at the output side. A predetermined triboelectric reading would represent the desired condition while any departure from the given reading would show that an undesirable change has taken place during the rolling pass.

Thus far we have outlined several sorting methods which are being used in actual industrial practice. These have employed the measurements of the magnetic properties of permeability, hysteresis and core-loss; mainly: the measurement and indication of thermoelectric effects, and the measurement of the triboelectric effect. The aforementioned physical properties of metals have been chosen for early discussion because their embodiments in commercially available equipments are completely instrumentalized.

That is to say, aside from following the normal operating instructions supplied with the equipment, little is left to the judgement of the operator or to his visual acuity. The equipment, in all cases, has been designed with a great deal of engineering background of fundamentals and an honest effort to foresee the usefulness and limitations of each type of test in its practical application, although there are those who lay claim to better results through the use of the dowser's wand.

Nevertheless, there are several sorting and identification methods in common use that should be mentioned here as companion methods. Very often,

such methods could and should be used to aid and ascertain the completely instrumental means.

The companion methods listed are well understood generally and require no further discussion aside from enumeration for the sake of completeness. These are the various forms of hardness testing, spark testing and, where permitted, fracture or bend testing. The well known methods of chemical spot testing have been highly refined in instrumental form, recently, by the Fisher Scientific Company's Electrograph. On rare occasions, steels can be sorted by the appearance or shade of the mill scale contained on their surfaces and it may be possible to utilize this factor in the form of a standard

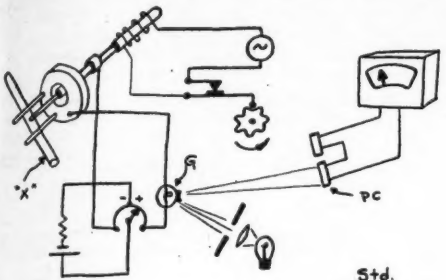


FIG. 11

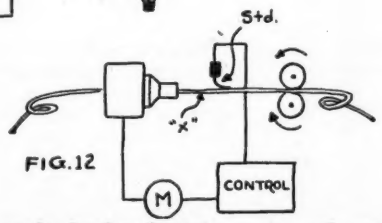


FIG. 12

method when a newly developed, portable reflectance filter photometer is announced. This device is intended to define and measure colors in terms of tristimulus coefficients and can be adapted to the accurate measurement of the total reflectance of shades of gray—which may be all that is necessary to sort a good many types of mixup situations.

Companion methods are important to users of various sorting instruments for several very good reasons. In the first place, all of the principles and methods discussed heretofore fail to divorce the effect of the constitution factor from that of the chemical one in their reading indications. When a sorting instrument indicator or a cathode-ray tube screen shows a difference of skeenteen divisions for two given specimens, this may mean that the difference is all chemical or it may mean that the difference is all constitutional or, for that matter, it may be that the difference indication is partly due to chemistry and partly to constitution; and all this is predicated on an assumption that there are no mass, contour, surface condition or subsurface variables to muddy the waters further.

A logical question then arises—"Now that you've got it, what have you got?" The answer to the question is elementary: "I don't know—but, with a few more tests, I can find out." And that reply generally brings about an argument. "How much will it cost to find out?"—"How much time will it take?"—"Will I have to put more than one man on the job?"—"Will he have to be a genius, gifted with second sight?"

To employ companion methods along with any one of the sorting equipments should cost very little more, and take very little more time, than it takes to use the equipment alone: providing that such a setup had been anticipated. The number of men that it takes depends upon the sizes of the individual problems and their frequency, or, in the case of a control application, the number of pieces that are to be tested per fiscal period. And a genius mental status is definitely not required to operate and apply sorting methods in accordance with text book and manufacturers' instructions.

However, a check-analysis department is required which exists as an entity and whose sole function is to know how to make use of sorting methods and to maintain sufficient standard and specialized equipment on hand to supplement packaged methods when and where necessary; a department to record day-to-day statistical data on results and make records of applied methods and new experiments; a department to disseminate its findings through the proper, authorized channels; a department which has immediate, special access to the order and shipping records of the company as well as its various laboratories and shops. And then, of course, the question arises as to just what benefit is to be derived from such a department.

Close control of scrap can be maintained by such a department, permitting a more economical melting practice—a huge cost item in itself. Quality control of the product within the producer's plant provides for a substantial saving in rejected material and lost "work hours" throughout the heating rolling, machining and fabricating stages. Delays and confusion due to over- or undershipment to a customer can be avoided or reduced to a minor happenstance. Reputation, good-will and liability losses can be avoided, or at least attributed to individual negligence and not to the technical know-how and attitude of the company as a whole.

All this has had to do with our so-called companion methods because it is only by additional application of these methods that the simple sorting instrument can be elevated to the status of an analyzer—fit to stand shoulder to shoulder, in its own place, with the chemical analyst. We have succeeded in providing some knowledge of the mechanism of magical gestures and even built a few magic wands; we have developed an entire vocabulary of incantations and embroiled ourselves in Maelstrom-like arguments which swirl around and around but finally disappear

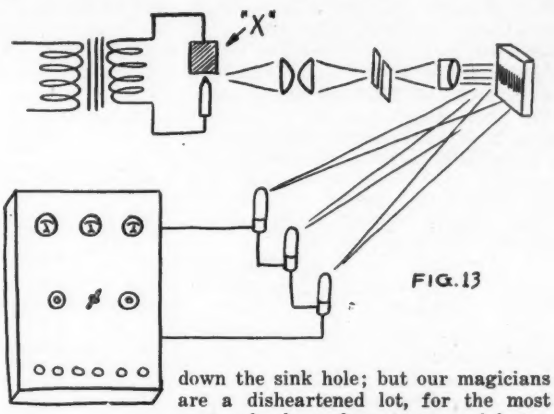


FIG. 13

down the sink hole; but our magicians are a disheartened lot, for the most part, who have few stages and but a small, highly skeptical audience only until they fail to accomplish magic, whereupon they quickly acquire a large skeptical audience. We know how to build magical props and can even supply a goodly number of clever and conscientious magicians, but industry must provide the stages in the form of check-analysis departments with know-how, mobility and authority.

A brief discussion of one further class of sorting and identification methods seems to be in order here. These are the spectro-methods as exemplified by the spectroscope, the spectrometer and other forms of spectrum analysis equipment. Spectrum analysis equipment comes into being by reason of the behaviour of the atomic and molecular structures of metals and all other elements when they are excited by either thermal or electrical activity.

Briefly, all elements are characterized by the number and arrangement of the electrons in their orbital structures. When placed within the field of a strong thermal, electrical or radiant influence, these electrons tend to absorb some of the available free energy and migrate into orbits further removed from the central nucleus. Properly speaking, under excitation the drift is toward discreet states of higher energy level. In the excited state, however, atoms are unstable and their electrons seek equilibrium conditions by falling back to their original states. During this regression, some of the absorbed

Continued on page 568

Correction Factors *for the* Balancing Effect *of a* Gas *in* One Leg *of a* Manometer

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THE increase in the distribution and value of natural fuel gas, together with the higher line pressures at which such gases are metered with orifice meters, has induced measurement engineers to analyze carefully all factors affecting the accuracy of their gas measurements. One of these factors is the balancing effect of the column of gas in the high pressure side (or low liquid side) of a manometer. (This is sometimes incorrectly referred to as "the unbalanced gas column.") The following notes have been prepared to show how the effect of this gas column may be taken into account. A table of factors and examples are included to show the magnitude of the effect.

Referring to Fig. 1, we will use the following notation:

h = the observed differential pressure, or "manometer reading"

ρ_L = density of the manometer liquid

ρ_G = density of the gas at pressure p_1 in the high pressure leg

p_1, p_2 = absolute pressures on the high and low pressure legs, respectively

We will assume that the temperatures of the pressure lines and manometer are equal, and that p_1-p_2 is small compared with either p_1 or p_2, so that at the plane A-B the weights of the fluid (gas) in the pressure connections above that plane may be considered equal.

Then at the plane C-D, we have

$$p_1 + h\rho_G = p_2 + h\rho_L \qquad (1)$$

or

$$p_1 - p_2 = h\rho_L - h\rho_G = h\rho_L(1-\rho_G/\rho_L) \qquad (2)$$

Thus, we see that the term $(1-\rho_G/\rho_L)$ is a correction factor to the manometer "reading" to give the true pressure difference in terms of a column of the manometer liquid.

This correction may be, and usually is, neglected in ordinary work, especially at low pressures. However, when high precision is required or when the over-all pressure (i.e. both p_1 and p_2) is sufficiently high it becomes significant and should be taken into account, as will be illustrated later. Also, the correction should be taken into account when a liquid flow (e.g. water) is being metered and the differential pressure is measured with an inverted U-manometer to the top of which compressed air is admitted to bring the water surfaces in the manometer legs to a convenient reading position.

The conditions stated above as a basis for equation (1) will be fulfilled in most actual installations, especially if the difference in elevations of the differential pressure source and manometer is small, and if the temperatures of the pressure connections are sensibly equal. However, there may be installations where there is not only a considerable difference in the elevations, but also an appreciable difference in the densities of the gas in the two pressure connections due to large differences in the pressures and temperatures. To extend equation (2) to include the effects of such a condition, let

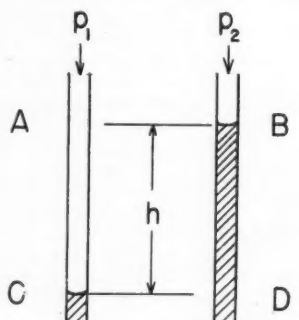

Fig. 1. A conventional liquid manometer for measuring the difference between two pressures.

Z = difference in elevation between the differential pressure source and manometer. The sign of Z will be positive (+) when the differential source is higher than the manometer, and negative (−) when lower than the manometer.

ρ_G = density of gas in the high pressure connection, corresponding to its pressure p_1 and average temperature, T_1.

ρ_g = corresponding density in low pressure connection at p_2, T_2.

Then at section C-D, Fig. 1

$$p_1 + h\rho_G + Z\rho_G = p_2 + h\rho_L + Z\rho_g \qquad (3)$$

and

$$p_1 - p_2 = h(\rho_L - \rho_G) - Z(\rho_G - \rho_g) = h\rho_L(1-\rho_G/\rho_L) - Z\rho_G(1-\rho_g/\rho_G) \qquad (4)$$

In equation (4), the factor $(1-\rho_g/\rho_G)$ measures the effect of any difference in the densities of the gas in the pressure connections, and as Z increases the magnitude of the full correction term increases.

In developing the above equations, nothing has been said about the units in which the various quantities are expressed. Of course, in the factors $(1-\rho_G/\rho_L)$ and $(1-\rho_g/\rho_G)$ it is sufficient if the densities be expressed in the same units. However, in the use of equations (2) and (4), in which these appear, it will be necessary to take account of the units in which the several quantities are expressed. In engineering work, it is customary to measure pressures p_1 and p_2 in pounds per square inch, h in inches, Z in feet, and densities (or specific weights) are expressed in pounds per cubic foot. Applying these units to equations (2) and (4) gives:

$$p_1 - p_2 = \frac{h\rho_L}{1728}(1-\rho_G/\rho_L) \qquad (5)$$

and

$$p_1 - p_2 = \frac{h\rho_L}{1728}(1-\rho_G/\rho_L) - \frac{Z\rho_G}{144}(1-\rho_g/\rho_G) \qquad (6)$$

Table I has been prepared to show, for several conditions, the magnitude of the correction term as given by equation (5). In preparing this table, the following values were used:

density of water at 60 F.
62.367 lb. per cu. ft.
density of mercury at 60 F.
846.322 " " " "
density of air at 60 and 1 atm.
0.07637 " " " "
specific gravity of methane
0.5549 air = 1
specific gravity of carbon dioxide
1.529 " "

As indicated by the definitions above, ρ_G and ρ_g are the actual densities of the gas at the plane A-B, Fig. 1, in the high and low pressure connections to the manometer. Hence, in computing their values the effects of "supercompressibility" (i.e. departures from Boyle's law) are to be taken into account. The supercompressibility factor for the gas in question should preferably be obtained from an actual determination, but may be obtained from such tables as are given in Bulletin TS 461 of the California Natural Gasoline Association. In this connection, it may be noted that at 60 F. the vapor pressure of carbon dioxide is 747.5 psia.,[1] and the value of the supercompressibility factor at 60 F. and 50 atm. was obtained by extrapolation from data given in Table I of Communications of the van der Waal's —Fund, No. 93. On the other hand, it was assumed that the density of the manometer liquid is unaffected by pressure over the pressure ranges here considered.

(1) Table 8 of The Vapor Pressure of Liquid and Solid Carbon Dioxide, R.P. 538, NBS J of Research, Vol. 10, No. 3, Mar. 1933.

The range of specific gravities of gases encompassed between methane and carbon dioxide includes most all gases of interest in the fuel gas industry, and with which manometers may be used under elevated pressures.

While the factors for a CO_2-water system are given for pressures up to the vapor pressure of CO_2, such a system would be of limited use because the solubility of CO_2 in water increases rapidly as the pressure is increased. The reason for including the CO_2-water factors is to illustrate the magnitude of the correction factor for gases having a specific gravity in the range of CO_2.

It was convenient, for showing the quantities used in developing the equations, to illustrate in Fig. 1 the conventional design of manometers, in which the two legs are of approximately equal areas. However, the analysis and equations apply to any design of manometer employing a liquid column to measure the difference between two pressures.

TABLE I

VALUES OF THE MANOMETER FACTOR $(1-\rho_G/\rho_L)$

p_1 atmospheres p_1 psia.	1 14.70	10 147.0	25 367.5	50 735	100 1470
air-water	0.999	0.988	0.969	0.938	0.876
air-mercury	1.0	0.999	0.998	0.995	0.991
methane-water	0.999	0.993	0.982	0.962	0.918
methane-mercury	1.0	0.9995	0.999	0.997	0.994
carbon dioxide-water	0.998	0.980	0.945	0.84	
carbon dioxide-mercury	1.0	0.9985	0.996	0.99	

In the great majority of commercial gas metering installations involving the measurement of a differential pressure, some form of recording gage is used. Most of these recording differential-pressure gages have a mercury manometer of unequal leg areas. In the larger leg, or pot, there is a float, which, through a system of linkages, operates a recording pen over a chart graduated in inches of water. Now the question arises as to what correction factor should be applied to the readings of such a gage?

First, consider only the manometer element of this gage. Obviously, this falls in the gas-mercury group, with correction factors ranging down to about 0.99. If these correction factors are applied to the "observed" mercury column readings, we obtain the value of the differential pressure in "corrected" inches of mercury.

Next, it is to be noted that the linkage system between the float and pen magnifies the differential in inches of mercury by a factor M (= 13.57) so that the pen indicates the value of the differential pressure in inches of water. Hence, if we have first obtained the differential pressure in "corrected" inches of mercury, multiplying this value by M will give the corresponding value in "corrected" inches of water. Now, the product obtained by multiplying a given quantity by two factors is independent of the order in which the factors are used. Therefore, the same result will be obtained if the "uncorrected" inches of mercury are multiplied first (mechanically) by the magnification factor M, to give "uncorrected" inches of water, and then this quantity is multiplied (manually) by the appropriate gas-mercury manometer factor to give "corrected" inches of water. Hence, with a mercury and float type of recording differential pressure gage, we will use the gas-mercury manometer factors regardless of the units employed for the indicating element of the gage.

As an (extreme) illustration of the possible effects of difference in elevation of pipe line and recorder, and the temperatures of the pressure connections assume that a gas having a specific gravity G, referred to air, of 1.46 is being metered with an orifice meter under the following conditions:

$p_1 = 125$ psia.

$h = 90$ in. water at 60 F.

$T_1 = 70$ F. av. temp. of high press. connection

$T_2 = 90$ F. avg. temp. of low press. connection

$Z = 50$ ft.

First, let it be assumed that h is the observed reading of a simple U-type water manometer so that

$$\rho_L = 62.367 \text{ lb/ft}^3.$$

For the conditions given above[2]

$$\rho_G = \left(2.7025 \times \frac{125}{530}\right) \times 1.46 = 0.9306 \text{ lb/ft}^3$$

This value may be used in equation (5) to give the manometer correction factor only; thus

$$p_1 - p_2 = \frac{90 \times 62.367}{1728}\left(1 - \frac{0.9306}{62.367}\right) = 3.248 \times 0.985 = 3.200 \text{ psi.} \quad (7)$$

Before we can proceed with the computation of the effect of the 50 ft. difference in elevation combined with the difference in the gas densities within the connection lines, as given by the right-hand term of equation (6), it will be necessary to compute ρ_g. In order to do this, the value of p_2 is required, and we have the choice of two procedures. The first is to use the result obtained above by the use of equation (5) to give a first approximate value of p_2. With this value of p_2, values of ρ_g and the elevation density term are computed, and a second and closer approximate value of p_2 is obtained. Then, if it seems worthwhile, the process may be repeated to obtain more exact values of the correction term.

The second, which is the mathematically proper procedure, is to use the relation

$$\rho_g = \frac{2.7025\, p_2\, G}{460 + T_2} \quad (8)$$

in equation (6) to give the following expression for the value of p_2

$$p_2 = \left[p_1 - \frac{h\rho_L}{1728}(1 - \rho_g/\rho_L) + \frac{Z\rho_G}{144}\right] \times \left[\frac{144\,(460 + T_2)}{144\,(460 + T_2) + 2.7025GZ}\right] \quad (9)$$

In using equations (8) and (9), it is still necessary to compute the elevation-density correction term if this is of interest. For the sake of illustration, the results by both procedures are given.

By the first procedure, the approximate value of p_2 is 121.80 psia. and that of ρ_g is 0.8738 lb/ft³.

The elevation-density term of equation (6) is

$$\frac{50 \times 0.9306}{144}\left(1 - \frac{0.8738}{0.9306}\right) = 0.0197 \text{ (or 0.02 very nearly)}$$

and thus the second (approximate) value of p_2 is 121.82 psia. Obviously, the effect of the small change in the value of p_2 will have no appreciable effect upon the elevation-density correction term.

By the second procedure, we have by equation (9)

$$p_2 = [125.00 - 3.200 + .323] \times \left[\frac{79200}{79200 + 197.3}\right] = 121.82 \text{ psia.}$$

Since, by the use of equation (5) alone the approximate value of p_2 was 121.80, it is evident that the elevation-density correction term amounts to 0.02 psi. as found by the first procedure.

Now let us suppose that in the above example the differential pressure had been measured with a mercury recording gage "geared" to indicate inches of water. The actual mercury column providing the balancing pressure between p_1 and p_2 is, approximately

$$90 \times \frac{62.367}{846.322} = 6.632 \text{ in.}$$

by equation (5)

$$p_1 - p_2 = \frac{6.632 \times 846.322}{1728}\left(1 - \frac{0.9306}{846.3}\right) = 3.248 \times 0.9989 = 3.245 \text{ psi.}$$

Following the first procedure discussed above, the value of the elevation-density correction term is 0.0199 (i.e. 0.02 as before). Thus, the adjusted differential pressure is 3.225 psi., as compared with 3.18 psi. when an ordinary water manometer was used.

(2) For an equation by which to compute the density of a gas, see ASME Fluid Meters Report, 4th Ed., par. 84, and equation [100(b)].

Standards *of* Mass

By LLOYD B. MACURDY, Chief, Mass Section, National Bureau of Standards, Washington, D. C.

REQUIREMENTS of modern commerce and industry make uniformity in standards of mass throughout the Nation no less important than uniformity of currency. Obviously, an even higher degree of uniformity is necessary among reference standards of mass kept by research laboratories to maintain high accuracy in scientific weighing.

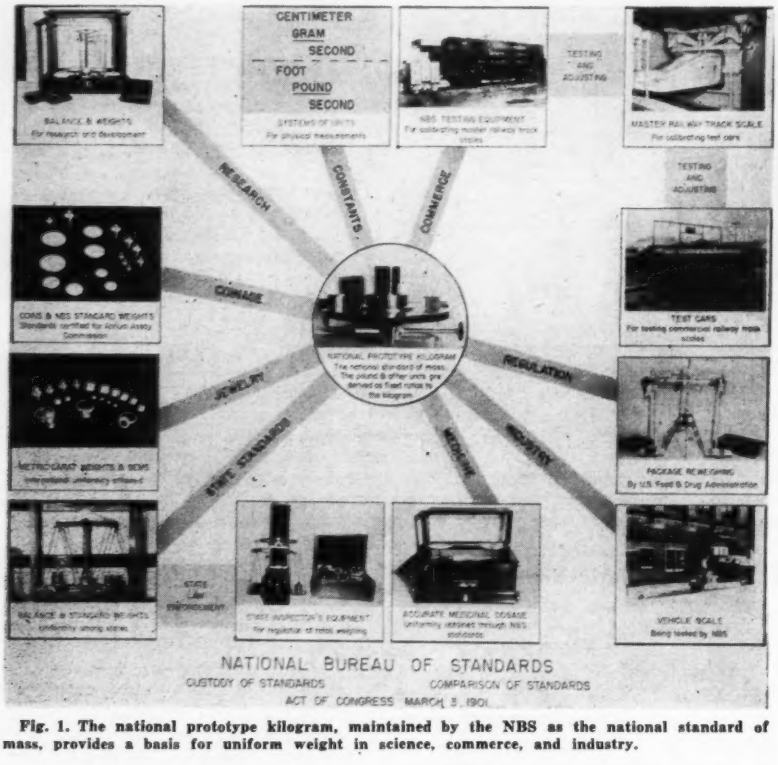

Fig. 1. The national prototype kilogram, maintained by the NBS as the national standard of mass, provides a basis for uniform weight in science, commerce, and industry.

High-Precision Measurements

The national standard of mass—a platinum-iridium cylinder about 1.5 inches high, 1.5 inches in diameter, and having a mass of almost exactly one kilogram—is maintained in a special vault of the National Bureau of Standards. The United States standard kilogram (Fig. 2), like the standard meter bar, is a copy of an international standard kept at the International Bureau of Weights and Measures at Sevres, near Paris. It is known as Prototype Kilogram No. 20. This prototype was established as the national standard by executive order in 1893. Since that time, the pound and other everyday units of mass have been defined by the ratio of their mass to the mass of this kilogram. Occasionally the national standard kilogram is removed from the vault to check the best secondary standards. These secondary standards include other platinum-iridium standards from 1 kilogram to 0.05 mg. and two 1-kilogram standards of nickel-chromium alloy. From these standards, values are derived for the working standards in the various customary and metric units in everyday testing in the Bureau's laboratories.

Weights submitted to the Bureau for calibration include the commercial classes of standards primarily used as the basis of State regulation of weights and measures, the laboratory classes of standards used in scientific research and development, and weights of special design required for industrial or technical work. In some classes of weights, such as those for precise balances, actual values are determined to the required precision; in others, such as weights for testing master track scales, it is only necessary to verify accuracy within specific tolerances. The Bureau's mass laboratory also investigates the degree of constancy and sources of variability in weights and makes studies to designate materials having good corrosion resistance, nonmagnetic properties, suitable density, and other desirable properties for weights. It is thus able to specify types of construction and tolerances for the different classes of weights.

The most accurate of the precision balances used by the Bureau in its calibration work can compare two platinum or platinum-iridium kilogram weights with an error of less than one part in 100,000,000 (Fig. 3). To make possible this high precision, the balance is kept in an air-conditioned room beneath the surface of the ground, and errors due to the heat of the human body are prevented by operating the balance entirely by remote control. Not only is the balance beam arrested and released in this way, but the interchanging of the loads on the pans and the addition of sensitivity weights are also accomplished without human intervention.

Fig 2. Prototype Kilogram No. 20, is a platinum-iridium cylinder 39 mm. in diameter and 39 mm. high. It was furnished the United States by the International Bureau in accordance with metric treaty of 1875. Recomparison with the international standard in 1937 showed that the U. S. standard has remained constant within one part in 50 million during approximately 50 years.

In determining the exact values of the best secondary standards of mass, the Bureau has found necessary many procedures not ordinarily employed in weighing. Thus, elaborate care is required in the determination of air buoyancy effects when the best secondary kilogram standards are compared with the standard platinum-iridium kilogram. The air buoyancy effects are important because of the difference in material of the weights being compared. Most of the standard weights in use in scientific research as well as in commercial regulatory work are of brass or some alloy of similar density, and the difference in air buoyancy for brass and platinum or platinum-iridium kilogram standards amounts to about 75 mg. Two finely finished nickel-chromium kilogram standards, calibrated by comparison with the prototype kilogram in such a way as to include the necessary correction for air buoyancy in their apparent mass, are used in calibrating brass weights. In the calibration of these nickel-chromium standards the density of air is determined with great care. Barometric pressure is accurately measured by means of a sensitive and highly reliable aneroid barometer especially designed for this work. Readings of the barometer be-

*Technical Report 1506, National Bureau of Standards.

tween turning points of the balance are used to evaluate momentary fluctuations in air pressure which may have appreciable effects on the turning points. The air temperature in the balance can be accurately measured since lag in thermometers is minimized by the extremely uniform temperatures. Relative humidity inside the balance case is indicated by an electric hygrometer. Once the values of these 1-kg. standards are determined, other standards of similar density can be compared with them, without extensive measurements of their density.

In the high-precision calibration of sets of weights, the Bureau follows the

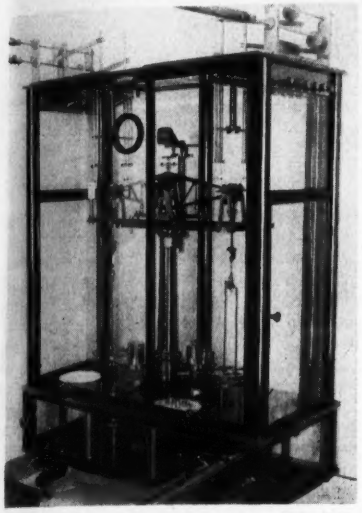

Fig. 3. The most accurate of the precision balances at the NBS is used to compare national standard kilogram with other secondary standards of mass. By means of rods (above and lower right), the balance beam is arrested and released, the loads on the pans are interchanged, and sensitivity weights are added.

general plan established by the International Bureau of Weights and Measures at Sevres, France. In this method, a summation of the weights from a set is determined by comparison with a known standard, after which the weights are intercompared by a series of weighings consisting of all possible combinations of various loads. These weighings are adjusted by the method of least squares to give values for the larger weights of the set and for a summation of the smaller weights. This latter summation is then intercompared in similar fashion to obtain values for each of a group of smaller weights and for a smaller summation. In this way, values are eventually obtained for all the weights in the set, the last series of observations giving values for the smallest weights, which are used in determining the sensitivity of the balance.

In general, the values obtained for the smaller weights will be slightly different from their preliminary values which were used in sensitivity determinations for the various weighings. The new values for the sensitivity weights must therefore be substituted in the computations and the entire com-

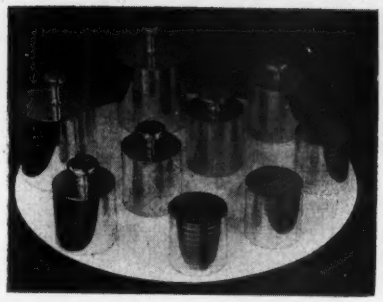

Fig. 4. Secondary standards maintained at NBS for the kilogram (left row), avoirdupois pound (center row), and troy ounce (right row).

putations repeated. Usually, after one recomputation, the values obtained for the sensitivity weights are identical with those substituted for the sensitivity weights. Because this method accurately subdivides the value of the prototype kilogram to give the values of the sensitivity weights, the results are based entirely on the value of the national standard. This procedure is used in the calibration of the Bureau's best set of platinum-iridium standards from 500 g. to 1 mg. and for smaller aluminum weights down to 0.05 mg. As standard weights certified by the Bureau are available in various denominations, it is not ordinarily necessary for other laboratories in this country to make these rather tedious computations.

The Bureau maintains accurate secondary standards (Fig. 4) for the avoirdupois pound, troy pound, and troy ounce, defined by their fixed ratios to the prototype kilogram. Groups of two 1-lb. avoirdupois standards, or three 1-lb. troy standards, or three 10-oz. troy standards are compared with the best secondary 1 kg. standards, the differences in each case being made up with small standard weights from the best platinum-iridium metric set. From these standards of customary units, values are derived for standards used by the States in regulation of commerce and industry.

To provide standards for modern microbalances, the Bureau has recently developed methods for calibrating small standard weights below 100 mg. with a precision of one or two ten-millionths of a gram. This precision—10 or 15 times as great as that now obtained by indirect methods of calibration—will permit the weighing of samples about

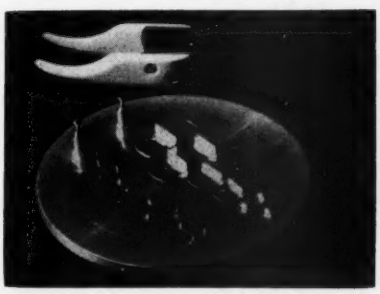

Fig. 5. Standard weights for calibration of standards for modern microbalances.

one-tenth as large as formerly. The resultant increase in the field of usefulness of microbalances should mean great savings to workers in such fields as atomic energy, where minute samples must be weighed with high accuracy.

Calibration of these small weights (Fig. 5) is carried out on high-grade assay balances (Fig. 6) using the method of double transposition in which loads are interchanged twice and a small sensitivity weight, usually 0.1 mg. or 0.05 mg., is added to obtain a sensitivity deflection. Equilibrium points are computed from a series of five or more turning points observed through a read-

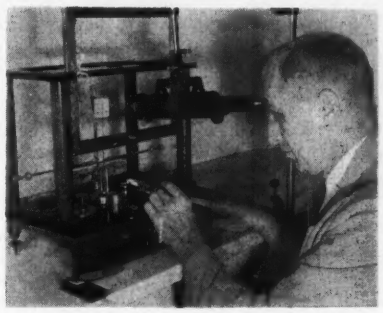

Fig. 6. Small high-precision balance in which is compared standard weights for microbalances with standards of mass maintained at NBS.

ing telescope on a finely divided index scale. The sensitivity is such that 0.1 scale division is equal to about 0.2 microgram. Thus, a reading accuracy of about one-twentieth of a scale division or slightly better is readily obtained by experienced observers.

In order to certify values below 100 mg. to an accuracy of 0.1 microgram, it is necessary to work down from 1-g. standards, intercomparing the weights to be calibrated in all possible combinations, and to repeat the entire computation to obtain values for the sensitivity weights which are accurate subdivisions of the 1-g. standards. The reliability of the balances used is such that for weighings expertly carried out under optimum conditions the values obtained by least square adjustment of the weighings are reproducible to 0.1 microgram. Moreover, discrepancies between observed and computed or adjusted values are usually not greater than 0.1 microgram. This accuracy, perhaps the highest ever obtained with the knife-edge type of balance is of special value in the weighing of radioactive material, making it possible to handle smaller samples with greater safety and to obtain small samples at less cost of time and labor.

Development of methods for calibration of extremely small weights has greatly simplified the problem of calibrating quartz microbalances directly in terms of known standard weights. This, in turn, makes possible the saving of much time, equipment, and labor formerly spent in direct methods of calibration. The quartz microbalance itself is now being intensively studied as part of a broad program now being

undertaken by the Bureau for the improvement of precision balances. Efforts are being made to improve the uniformity of its fabrication and to increase its capacity. The construction of the equal-arm knife-edge type of balance is also under study, with the object of attaining greater accuracy through improved design, use of new materials, and avoidance of troublesome temperature effects.

In recent years, the increasing interest in scientific research in this country has brought about a corresponding increase in the number of standard weights submitted to the Bureau for calibration. The largest part of this work involves sets of weights in the following combinations of units: 5, 3, 2, 1, 1; 5, 2, 2, 1, 1; and 5, 2, 1, 1, 1. At present all computations involved in the separate calibration schemes used for each of these combinations are performed with a slide rule or a desk calculator and are then checked in detail and reviewed. Plans are under way to do a large part of this work by means of a computing machine designed to give a simultaneous solution for the values of the weights from a series of equilibrium points as observed on a balance. For this purpose, a single series of observations has been devised by means of which weights in all three of the above combinations may be calibrated. Such a scheme makes possible the construction of a machine designed for the simultaneous solution of the one series of observations and its use to compute values for sets of weights in all three combinations of units. This should largely eliminate errors of computations and result in great savings of time and effort in the Bureau's weight calibration program.

Fig. 7. Two standard test weight cars, owned and operated by the NBS, are used for calibrating and adjusting master railway track scales of the Nation's railroads. A total test load of 80,000 lbs. is carried by each car; consists of seven 10,000-lb. weights, three of which are mounted on the small truck (right), and the truck itself, which is adjusted to weigh 10,000 lbs. Auxiliary equipment is carried on the car for proper handling of test weights.

Commerce and Industry

As the custodian of the national standards of physical measurement, the NBS not only sets up and maintains the basic standards of length, mass, time, and other physical quantities, but also undertakes the necessary research leading to improvements and refinements in such standards and measurement methods. At the same time, the Bureau constructs, maintains, and intercompares reference and working standards which are calibrated in terms of the national standards and used in science, engineering, industry, and commerce. These services are performed for agencies of the Federal and State governments, scientific societies, educational institutions, and firms or individuals within the United States engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments.

While the Constitution gave Congress the power "to fix the standard of weights and measures," weights used during the early days of the Republic were far from uniform. Not only was there much uncertainty as to the value of the pound, troy ounce, and other units, but the fineness of United States coinage had been questioned. To remedy the situation, a small Office of Standard Weights and Measures was set up in 1830 in the Treasury Department as part of the Coast Survey. Through this Office definite values were established for the pound and other common units. Standard weights and balances and standards of length and capacity were constructed, and accurate copies were distributed to the various States and customs houses. In this way a high degree of uniformity in standards was established and maintained. Finally, in 1901, in response to the growing need for a national scientific laboratory similar to those of Germany and Great Britain and in recognition of the high standards that had been established in weights and measures, the Congress enacted a law establishing the National Bureau of Standards.

The uniformity which the bureau has been able to achieve in weights of all types and denominations—from 0.05-mg. weights for microbalances to 10,000-lb. test weights for cargo scales—has been of great economic importance to the producing, manufacturing, processing, and distributing agencies of this country and to all purchasers of commodities. Essentially, the Congress has left to the individual States the regulation of commercial weighing devices and operations. In this work the NBS serves principally in an advisory capacity. However, uniformity between the States is maintained by the periodic comparison of State standards with the primary standards kept at the Bureau.

Weighing devices and weights employed by other Federal agencies, such as the weights used by the Bureau of Internal Revenue to weigh the products of distilleries or those used by the Customs Bureau to weigh cargoes, are tested and calibrated directly by the NBS. Thus, through the introduction of the metric carat, based on the standard kilogram, uniformity in the measurement of the weight of gems has been achieved. Previously the many different values of the carat in use had caused much difficulty in customs work. Likewise, uniformity in the manufacture of drugs is now possible through the use of certified weights. Weights and balances tested by the National Bureau of Standards are used by the Food and Drug Administration in its regulatory work. In accordance with an Act of Congress dated March 4, 1911, the weight and fineness of coinage is verified each year through comparison with standard weights of the National Bureau of Standards.

Over 30 years ago the Bureau began the testing of railway track scales in order to provide a uniform basis for the weighing of carload shipments (Fig. 7). At the same time errors in track scales ranged from 30 to 21,600 lb. per 100,000, and it was not unusual for a load which was weighed at 100,000 lb. in one locality to be "weighed in" at its destination as 80,000 lb. Discrepancies of this magnitude required check-weighing all along the route and, as the results of check-weighing were often not in agreement, caused much confusion. In the 34 years from 1914 to 1948, truck scales meeting tolerance requirements increased from 33 to 84 percent of the total, and a reduction in mean errors of the scales from 0.57 percent to 0.15 percent was effected.

Tests weights certified by the Bureau for values of 500 lb., 1000 lb., or more are used to determine the accuracy of large-capacity vehicle scales used in industry and commerce. With the rapidly expanding use of the highways and the increasing size of truck loads, scales of this kind have become increasingly important. As the result of a survey conducted by the Bureau in 1936, which showed that the vehicle scales of this country were not sufficiently accurate, the regulatory agencies throughout the United States have greatly improved the accuracy of their vehicle-scale testing methods. Large errors in transportation charges and much ex-

pensive litigation have thus been avoided.

Office of Weights and Measures

To aid in the translation of the basic standards to the channels of industry and commerce, the Bureau established in 1947 an Office of Weights and Measures whose over-all function is to promote the extension, raise the standard of efficiency and coverage, and increase the degree of uniformity of State weights and measures supervision throughout the United States. A definite program of assistance to State and local departments of weights and measures as well as to business and industry has been set up and successfully pursued.

A large part of the activity of the Office of Weights and Measures consists of consultative services rendered through correspondence; through visits to the Office by representatives of Federal agencies, business and manufacturing concerns, and weights and measures officials; and through visits of members of the Office to weights and measures officials in their own jurisdiction. The field of inquiries is broad, embracing the drafting of new legislation; the interpretation of laws, specifications, tolerances, and regulations; the design of testing equipment; methods of test of commercial equipment; the reporting of activities in different weights and measures jurisdictions; problems of and plans for weights and measures administration; planning and conducting weights and measures conferences; and training schools for State departments.

Modification *of* Portable Strain Indicator *for* Use *with a* Closed External Bridge Circuit

C. E. BOWMAN, Assistant Professor and W. J. CRAIG, Research Associate

Theoretical and Applied Mechanics Department, University of Illinois

THERE are many strain gage applications such as torsional weighing bars and elastic proving rings where it is desirable to use a closed external bridge circuit. A closed circuit consisting of four active gages is used to obtain increased sensitivity, to obtain better temperature compensation, and to average out unwanted strain components. The Baldwin "Type K" portable strain indicator may be readily modified so that it can be used with an external bridge circuit following the same operating procedure as with the new Baldwin "Type L" indicator which is designed for use with such an external bridge circuit.

The following procedure is used in making the modification. Two binding posts, X and Y, are mounted on the front panel (Fig. 1) and are insulated from it by means of fiber washers and sleeves. An X-Y jumper is mounted between the two binding posts. Next locate the solder lug on the underside of the sub panel to which are connected one lead from each of the 120-ohm resistors R_3 and R_4, the orange wire from the transformer, and the lead from the 16500-ohm resistor R-13 (Fig. 2).[1] The orange wire from the transformer and the lead from the 16500-ohm resistor R-13 are removed from the lug and connected to binding post X. The lug, to which one lead from each of the two resistors R_3 and R_4 is still attached, is then connected to binding post Y.

With this modification, the operating instructions using four active gages in an external bridge circuit are the same as the instructions for the "Type L" strain indicator,[2] and are given below.

1. Open the jumper connection between binding post X and terminal Y.
2. Connect the power input terminals of the external bridge to the top and bottom binding posts at left of panel.
3. Connect one bridge output terminal to either of the inner pair of binding posts at left of panel.
4. Connect the other output terminal to binding post X.

The instrument has an accuracy of 99 percent or better for gages whose resistance is in the range from 80 to 500 ohms.

When using two external gages, replace the X-Y jumper and operate the instrument in the usual manner.

The scope jack shown on Fig. 1 may also be added to the "Type K" instrument for use in making dynamic strain measurements as suggested by Worley.[3]

REFERENCES

(1) Instruction Book, Portable Strain Indicator, Type K, Book No. 1538A, Baldwin Locomotive Works, Phila, Pa.

(2) Instruction Book, Portable Strain Indicator, Type L, Bulletin 312, Baldwin Locomotive Works, Phila., Pa.

(3) W. J. Worley, "Simplified Dynamic Strain Equipment," *Instruments*, Vol. 21, April 1948, pages 330-332.

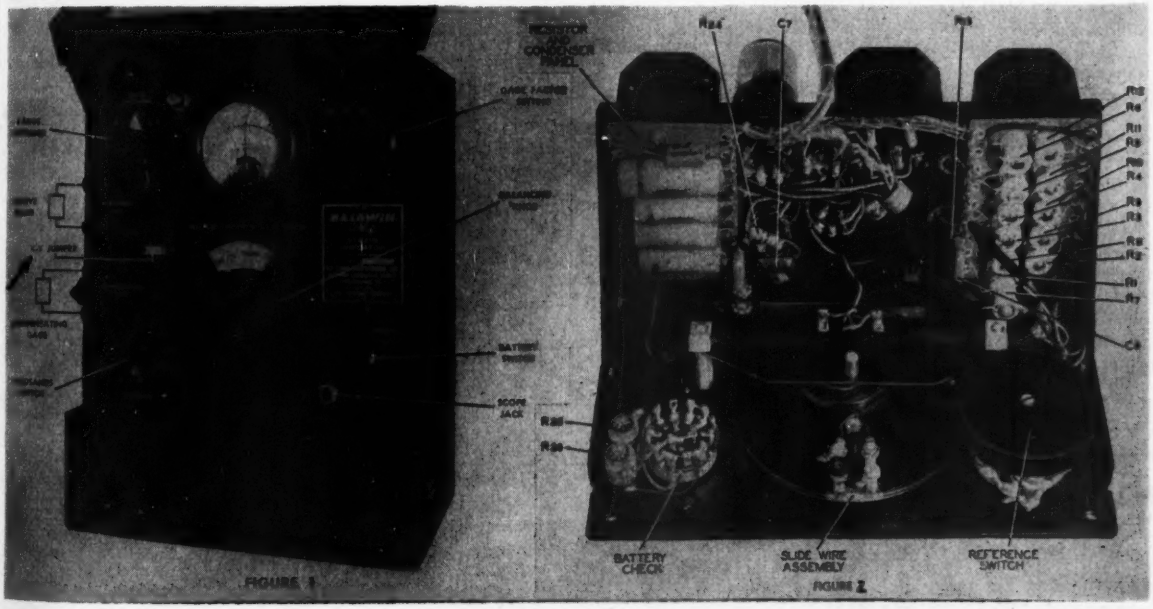

FIGURE 1 FIGURE 2

Photoelectric Measurement *of* Dust

By JOHN E. COOLIDGE, Associate Professor of Engineering Research and
GEORGE J. SCHULZ, Research Assistant, The Pennsylvania State College*

ABSTRACT.—*Available methods for measuring smoke density are described. The photoelectric absorption meter used at Pennsylvania State College is discussed in detail. The original one-phototube model is described. The more-sensitive two-phototube model, together with its bridge circuit, is described in detail. The factors associated with sampling are discussed. A brief theory of light absorption by dust loading is presented.*

Introduction

CLEAN-UP campaigns of industrial cities such as Pittsburgh have required the development of instruments to measure smoke density, or dust loading. Instruments are needed also to determine the efficiency of apparatus designed to clear the air of its undesirable contamination. The following methods are available for measurement of smoke density:

1. Filter-paper "blackness test";[1]
2. Volume sampling;[2]

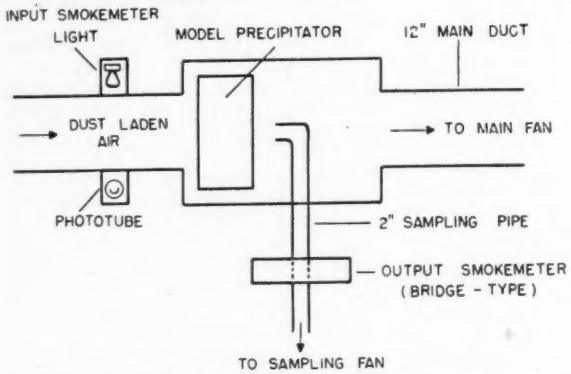

Fig. 1. Equipment for calibration.

3. Application of small electrostatic, cyclone, and thermal air cleaners;
4. Photoelectric or bolometer[3] devices.

In the filter-paper blackness test, the smoke is drawn through a filter paper for a specified length of time and the resulting blackness of the filter paper is compared to a standard color chart. In volume sampling, the same procedure is followed but the sample is weighed and, from the known weight and volume of air passed through the device, the dust loading can be calculated.

When small air cleaners are used to measure smoke densities, the smoke is passed through the air cleaner, which operates near 100 percent efficiency, and the dust collected in the air cleaner is weighed. The loading then is calculated as in the volume-sampling method.

All the methods described above have the disadvantage of not permitting continuous readings. In order to overcome this difficulty, photoelectric methods have received attention because these devices make continuous readings of dust loadings possible. However, it is extremely difficult to obtain quantitative information with photoelectric devices, although qualitative information is acquired easily.

This article describes a laboratory installation used at The Pennsylvania State College for measurement of the efficiency of an experimental electrostatic precipitator. A short discussion of the theory of the instrument is included.

As shown in Fig. 1, a two-inch sampling pipe was used to measure the loading coming from the precipitator. A sampling pipe is often used in practice because the main pipes are often not accessible and sampling permits a better location of the smokemeter. In order to obtain a representative reading in the sampling pipe, it is necessary to know how velocity in the sampling pipe affects the indication of the smokemeter, and whether the loading in the sampling pipe is representative of the loading in the main duct.

Photoelectric Absorption Meter

A schematic diagram of the first absorption meter constructed is shown in Fig. 2. It consists simply of a light source and a single phototube, which is connected to a cathode follower, or current amplifier. The current through the phototube depends on the intensity of the light falling on the tube, which in turn depends on the density of the dust in the duct. The current develops a signal across the 1-megohm resistor in the grid circuit of the cathode follower, which drives an Esterline-Angus recorder. Thus the signal recorded depends on the dust density.

This absorption meter, or smokemeter, has very good stability but low sensitivity. However, the instrument is very suitable for the heavy dust loadings which are usually present at the input of precipitators, especially when a long absorption path is possible. However, when small pipes are used for sampling, or when relatively clean air coming from precipitators is measured, greater sensitivity is needed.

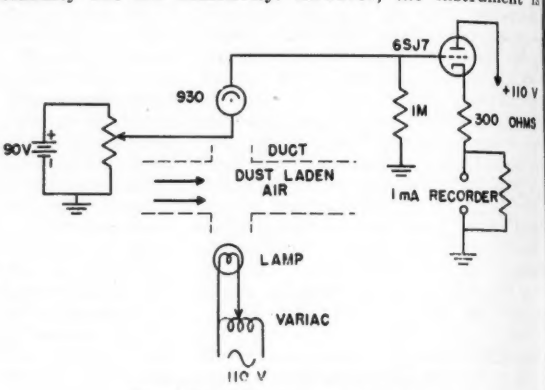

Fig. 2. Schematic of input smokemeter.

Higher sensitivity can be achieved by using two photocells in a bridge-type circuit. The two photocells are shown in Fig. 3. Light from the single-light source shines on the two phototubes. The dust-laden air is in the absorption path of one tube. Clean air is in the path of the other. The output of the phototubes is matched in a bridge circuit, as shown in Fig. 4. The unbalance of the bridge is a measure of the dust content in the sampling pipe. The high sensitivity required is thus obtained by measuring the difference rather than the absolute magnitude of the light impinging on the phototubes. It might be mentioned that initially two light sources supplied by a single regulated transformer were tried, but the erratic light fluctuations and the difference in phototube characteristics made the operation unstable.

Construction Details

The RCA type-930 phototubes are mounted on opposite sides of a 6-8 volt light source #2330. Spectacle-type lenses on each side of the sampling pipe protect the optical system from the dust and facilitate lens cleaning. A Kodak shutter between the light source and the second phototube adjusts the light impinging on the tube, and thus provides means for balancing the output of the two tubes. The output of the bridge circuit is fed to a General Radio #715-A d-c. amplifier, connected to an Esterline-Angus 1-ma. recorder.

Continued on page 544

*Now a Graduate Assistant at MIT.

The Direct-reading D-c. Strain-gage Bridge

By ROBERT W. TROKE, Flight Test Engineer, North American Aviation, Los Angeles, Calif.

Editor's Note: This is the second of two installments. The first installment, covering "Types of Bridges" and "Calibration of Bridges," appears in our April 1951 issue.

Practical Considerations

This discussion will include equations and information most useful to the engineer using strain-gage equipment or designing and using force instrumentation. This discussion will begin with a brief analysis of the basic Wheatstone bridge used for the direct-reading d-c. strain-gage bridge.

The Strain-gage Bridge Circuit

Fig. 1 shows a basic Wheatstone bridge circuit. No current will flow in the output circuit of the bridge as long as the resistance ratio R_A/R_B is equal to the resistance ratio

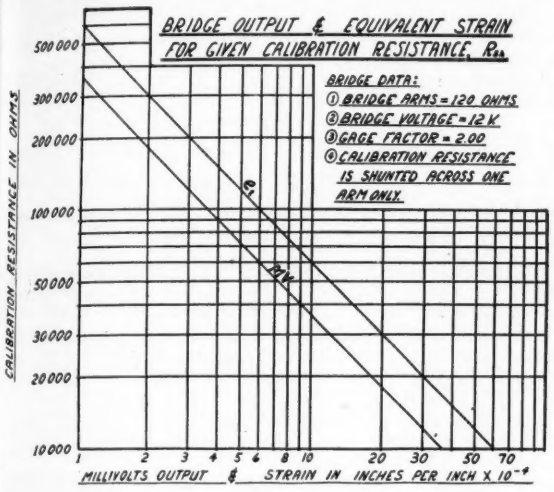

Fig. 10

R_C/R_D. The symbol R designates the resistance of a bridge arm and the subscripts $_A$, $_B$, $_C$, and $_D$ indicate the particular bridge arm. When this ratio is upset by a change of resistance of one or more arms, current will flow through the instrument. The magnitude of the output current is proportional to the bridge voltage V. Assuming a Wheatstone bridge with all four arms of equal resistance, the output voltage produced by a change in resistance of one arm may be written as:

$$v = \frac{V\,(\Delta R/R)}{4} = \frac{V(\Delta R)}{4R}. \qquad (5)$$

This output voltage v must be measured with an infinite- or high-impedance voltmeter. Only bridges with arms of equal resistance are considered in discussing the direct-reading d-c. strain-gage bridge.

The voltage output produced by a resistance change in any number of bridge arms may be written as:

$$v = \frac{V[(\Delta R/R)_A + (\Delta R/R)_D - (\Delta R/R)_B - (\Delta R/R)_C]}{4}. \qquad (6)$$

The current output may be calculated by applying Ohm's law to either equations (5) or (6). The resistance of the entire instrument circuit may be regarded as the sum of the resistance of the bridge at its output terminals and the resistance of the indicating instrument. For practical purposes the resistance of the bridge at its output terminals may be regarded as equal to the resistance of one arm. In the same way, the resistance of the instrument circuit may be regarded as equal to the instrument resistance R_m, neglecting the comparatively small resistance of the meter leads. The resistance of the instrument circuit is then $(R+R_m)$. The output current i produced by the change in resistance of one arm of the bridge may be written as:

$$i = \frac{V(\Delta R/R)}{4(R+R_m)}. \qquad (7)$$

An equation for the output current produced by the change in resistance of any number of arms may be written by replacing the numerator of this equation with the numerator of equation (6).

A complete schematic diagram of a strain-gage channel is shown in Fig. 7. To the simple strain-gage bridge circuit of Fig. 1 has been added a balance circuit, an attenuation circuit, and a calibration circuit. The balance circuit is shown just to the right of the strain-gage bridge and consists of the fixed resistor R_1 and the variable center-tapped resistor R_2. The attenuation circuit is to the right of the strain-gage bridge in Fig. 7 and consists of a three-position switch and two fixed resistors. The calibration circuit is shown to the left of the bridge in Fig. 7 and consists of a calibration switch and a calibration resistor R_{sh}.

The balance circuit makes it possible to balance the bridge so that no current flows through the instrument when no load is applied. The resistance R_1 and R_2 of Fig. 7 should be kept as high as is practical for balancing the strain-gage bridges used. If R_1 is 3,500 ohms and R_2 is 10,000 ohms, a maximum gage resistance difference of about 2 percent can be accommodated. The resistance of 120-ohm SR-4 gages is held to a closer tolerance than 1 percent, but may be further changed by installation. This may unbalance the bridge additionally.

The attenuation circuit is so arranged that the bridge voltage may be set at either 12 volts, 6 volts, or 4 volts. When a bridge voltage of 12 volts is selected, the circuit is not attenuated, when 6 volts is selected the circuit is attenuated ½, and at 4 volts, ⅓. When many different channels are being recorded on a multi-channel oscillograph, individual control of sensitivity of each channel is often found desirable in order to keep galvanometer deflections within desired limits.

Many changes could be made in the circuit of Fig. 7 without impairing its effectiveness. However, the attenuation circuit was put in the battery circuit rather than the instrument circuit for two main reasons:

(1) It is desirable to keep the bridge voltage low and run the strain gages as "cool" as possible for better temperature compensation and more reliable results.

(2) The drain on the battery is reduced and its life and stability is increased.

The use of the attenuation circuit is discussed further under a later subheading, "Bridge Sensitivity and Reliability of Data."

The calibration circuit makes it possible to determine the sensitivity of the system by observing the instrument deflection for a known bridge unbalance or ΔR. Since the ratio $\Delta R/R$ is equal to $R/(R+R_{sh})$ for an unbalance caused by a given calibration resistance, the voltage output of a bridge produced by a given calibration resistance may be written as:

$$v = \frac{VR}{4(R+R_{sh})}. \qquad (8)$$

R_{sh} is always much greater than R. For a given bridge with a fixed bridge voltage, the value of the calibration resistance R_{sh} is related to the bridge output voltage by an inverse logarithmic relationship. This relationship is plotted on logarithmic paper by the straight line designated as MV in Fig. 10. This plot is for a standard bridge using 120-ohm legs and 12 volts on the strain-gage bridge. The millivolts output may be changed to milliamperes output by simply applying Ohm's law. The current flowing through a galvanometer, for example, is obtained by dividing the

millivolts output by the resistance of the instrument circuit, milliamperes = $MV/(R+R_m)$.

The current output produced by a given calibration resistance may be written as:

$$i = \frac{VR}{4(R+R_{sh})(R+R_m)} \quad (9)$$

From equation (2), we may write $\Delta R/R = C\ e$. From this and equations (6) and (7), we may write equations for the strain-produced output of a strain-gage bridge as follows:

$$v = \frac{VC(e_A+e_D-e_B-e_C)}{4} \quad (10)$$

$$i = \frac{VC(e_A+e_D-e_B-e_C)}{4(R+R_m)} \quad (11)$$

Inspection of these equations shows why strains of like sign must be applied to opposite arms of the bridge and strains of opposite sign to adjacent arms of the bridge. The output of the bridge would not be affected by equal strains of like sign on gages A and B, for example. The bridge arms must be employed in such a way that the unbalance of the arms produced by strain do not cancel each other.

Equations (10) and (11) may be written more conveniently for use in design as:

$$v = \frac{VCe_t}{4} = \frac{VCe_xN_E}{4} \quad (12)$$

$$i = \frac{VCe_t}{4(R+R_m)} = \frac{VCe_xN_E}{4(R+R_m)} \quad (13)$$

Equations (12) and (13) may be rewritten in convenient form for determining total indicated strain e_t or the actual strain e_x when the bridge output is known.

$$e_t = \frac{4v}{VC} \quad \text{(or)} \quad e_x = \frac{4v}{VCN_E} \quad (14)$$

$$e_t = \frac{4i(R+R_m)}{VC} \quad \text{(or)} \quad e_x = \frac{4i(R+R_m)}{VCN_E} \quad (15)$$

As previously explained, equations (10) and (11) must be qualified by saying that the value of e in each equation is the indicated strain. The indicated strain is equal to the actual strain when $N_E = N$. Equations (12) through (15) are convenient to use for the design of force instrumentation. We know that the total strain indicated e_t is increased as we increase the number of active arms N. The value of e_t may conveniently be regarded as equal to the actual strain e_x multiplied by the effective value of N, $e_t = e_xN_E$. The effective value of N, N_E, for bridge type A1 is 2; A2, about 2.6; A3, about 1.4; B1, 4; and S1, about 3.9. The exact values of N_E were tabulated in the discussion of resistance calibration.

In Fig. 8 e_t is plotted against e_x for each bridge. The slope of the line for each bridge is equal to the value of N_E for that bridge type. We see that when the actual strain equals the indicated strain, the effective value of N is equal to the actual value of N or the number of active gages. N_E is never greater than N; its value is always either equal to or less than the value of N.

The deflection of a galvanometer trace for any bridge output current may be determined from the sensitivity of the galvanometer. This information is supplied by the manufacturer. One galvanometer on the market has a sensitivity of approximately 30 inches per milliampere. Should the value of the output current be found to be 100 microamperes, for example, a deflection of about 3 inches could be expected. The deflection of an oscillograph trace may generally be read to 0.01 inch. Reasonable reading accuracy may generally be obtained from a maximum deflection of 1 to 2 inches. When the meter deflection is known for a value of R_{sh} used in a table like that shown in Fig. 9, the strain required to produce this deflection for any of the bridges listed can be quickly de-

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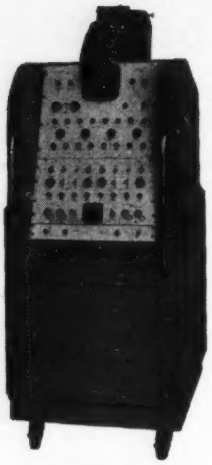

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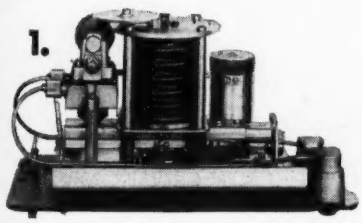

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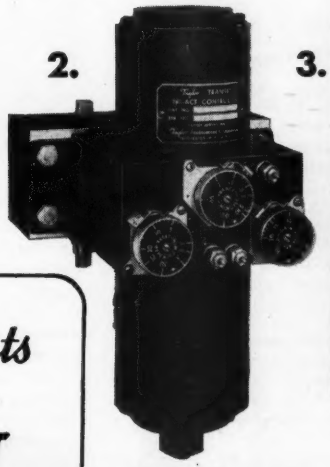

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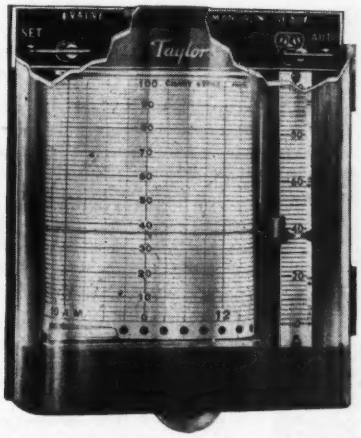

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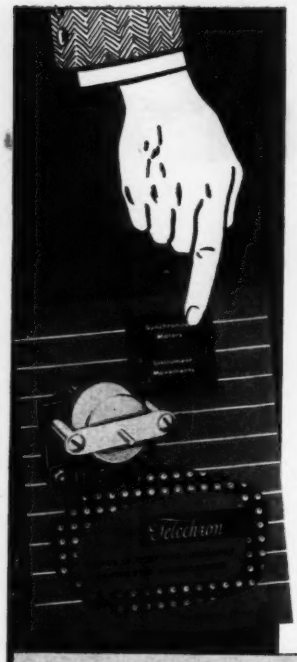

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termined. Such a table may serve as a useful reference for the design and use of force instrumentation.

Equations (8) and (9) may be rewritten to show the relationship of the value of calibration resistance to bridge output and equivalent strain. They become

$$R_{sh} = \frac{RV}{4v} - R \quad \text{or} \quad R_{sh} = \frac{R\,V}{4\,i\,(R + R_m)} - R \qquad (16)$$

Values of R_{sh} are plotted against millivolts output in Fig. 10.

The value of calibration resistance equivalent to any total indicated strain (and vice versa) may be determined from the following equations:

$$R_{sh} = \frac{R}{C\,e_t} - R \quad (\text{or}) \quad e_t = \frac{R}{C(R+R_{sh})} \qquad (17)$$

It should be noted that this relationship is independent of bridge voltage. In Fig. 10, values of calibration resistance are plotted against the indicated total strain; the result is the straight line designated by e_t.

The value of R_{sh} for any equivalent stress may be determined when the equivalent stress for a given R_{sh} is already known. This statement is also true for an equivalent strain or force. For convenience, the term force will be used to designate any of these quantities. Using the subscript $_1$ to designate the known relationship and the subscript $_2$ to designate the unknown relationship, we may write:

$$R_{sh2} = \frac{(\text{equiv. force})_1\ (R + R_{sh1})}{(\text{equiv. force})_2} - R \qquad (18)$$

This equation may be rewritten to obtain the equivalent force for any value of calibration resistance as:

$$(\text{equiv. force})_2 = \frac{(\text{equiv. force})_1\ (R + R_{sh1})}{R + R_{sh2}} \qquad (19)$$

Suppose, for example, that a 30,000-ohm calibration is known to be equivalent to a 5,550-pound load for a certain force-measuring device using a strain-gage bridge with 120-ohm arms, and it is desired to know what load will be equivalent to a calibration resistance of 100,000 ohms. Substituting in equation (19) we find the load to be 1,670 pounds.

Oscillograph galvanometers are probably the most common instruments used with the direct-reading d-c. strain-gage bridge. These galvanometers are rated in terms of sensitivity and natural frequency. Galvanometers should be used considerably below their natural frequency. Some mention of galvanometer damping seems in order. Galvanometer damping is necessary for a flat response and the prevention of "overswing" of the galvanometer. "Critical damping," or 100 percent damping, is generally defined as the amount necessary to just prevent overswing when a square wave of current is applied. Galvanometers used with strain gages for low frequency measurements, as in most flight testing, are normally operated at about 64 percent damping with satisfactory results. Information and directions concerning damping are supplied by the manufacturer of the galvanometers used. Low-frequency oscillograph galvanometers are often damped by the electromagnetic induction of circulating currents within the galvanometer circuit. These currents are often controlled by controlling the shunt and series resistances in the galvanometer circuit, and the method is often (incorrectly) called "resistance" damping. The "damping resistance" includes the resistance of the bridge circuit as seen at its output terminals plus the resistance of the leads to the galvanometer. A fixed resistance may be shunted across the galvanometer to obtain a lower damping resistance than that obtained from the strain-gage bridge alone. Damping resistance may be increased by using a fixed resistance in series with the galvanometer leads. Galvanometer damping may often be set up so that strain-gage bridges with a considerable range of resistance may be used without frequent changes of damping resistance.

Strain gages of 120 ohms are considered in most of the examples given in this discussion because 120-ohm gages are made in the greatest variety of configurations by the manufacturer and because of their comparatively low resistance. It is important that the bridge resistance be low

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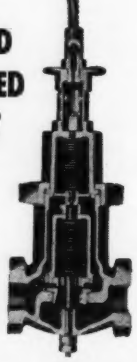

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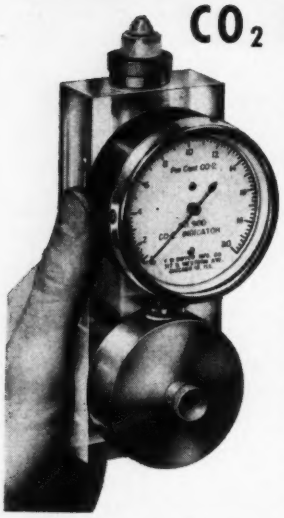

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Measurement of Forces

The possibilities of using strain gages for the measuring of force and motion seem almost unlimited. *It is altogether reasonable that there is a strain-gage setup that will measure any force or motion that causes—or can be made to cause—a related strain on any surface suitable for mounting a strain gage.* Many strain-gage force-measuring devices are in popular usage and are commonly known as transducers or pick-ups; they are used to measure pressure, load, or deflection.

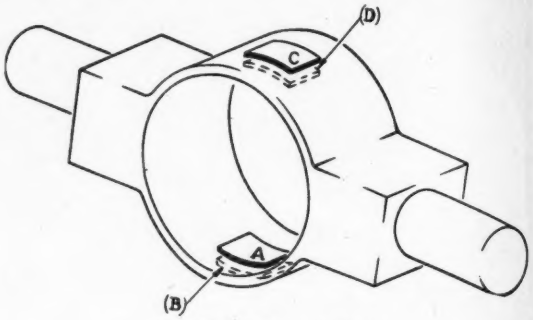


Fig. 11. Strain-gaged ring.

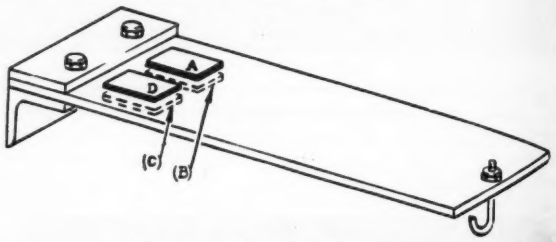


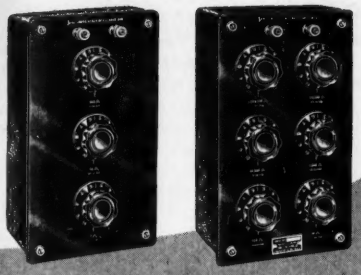
Fig. 12. Strain-gaged cantilever beam.

Figs. 11 and 12 show two strain-gage applications for measuring either load or deflection. Strain-gage rings are probably most used to measure loads while bending beams are commonly used to measure both loads and deflections.

In designing force-measuring instruments it is desirable to obtain maximum output without overloading either the device or the indicating instrument. Equations (14) and (15) are convenient for determining the necessary strain. The required dimensions of the pick-up device may be determined from handbook formulas for stress and strain.

Often a force may be measured without a special device by bonding strain gages directly to a structural or a control member such as a torque tube or link. This can often be done in measuring control forces in flight testing. Suppose, for example, that it is desired to measure a moment by placing "X" type shear gages on a torque tube. The shear stress of the tube may be calculated using handbook formulas from either the maximum angle of twist expected or the maximum torque moment expected. The bridge output that can be expected for maximum load can be calculated from equation (12) or (13). The value of e_x is obtained by dividing the shear stress by 2 G. For the low-impedance oscillograph, equation (13) is used. Fig. 13 shows an installation of a shear bridge on a torque tube to measure either hinge moment, angular deflection, or shearing strain. One installation could, of course, be used to measure all of these quantities.

Probably the simplest method of load measurement is to place an A2 axial bridge on a specially designed link like that shown in Fig. 14. Links like this can be installed in prototype models in order to make important load measurements. Many design engineers are today designing prototype models with uniform areas free of stress concentrations at various locations to facilitate making strain and load measurements. This has been found advantageous and the future trend will likely be toward more of such design.



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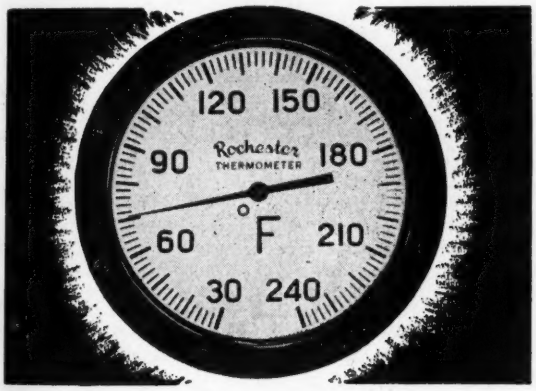

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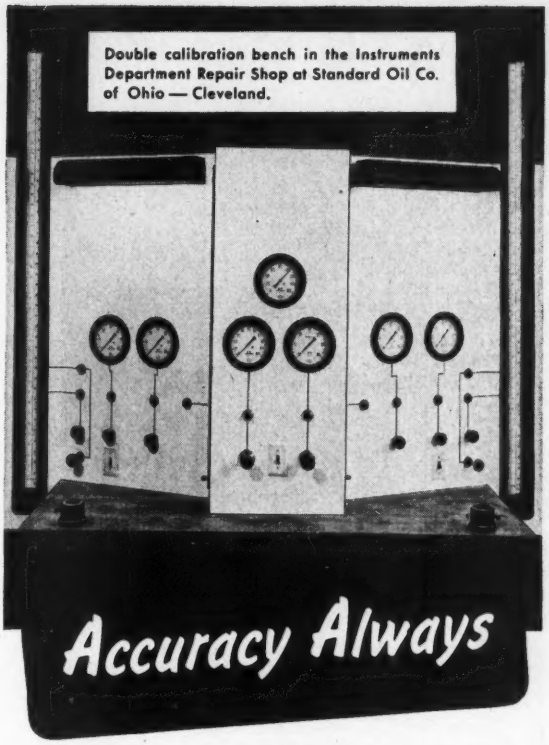
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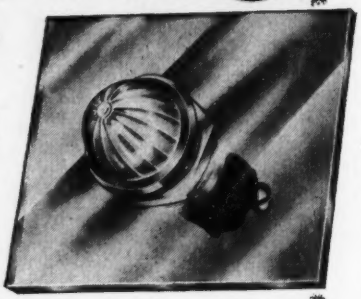

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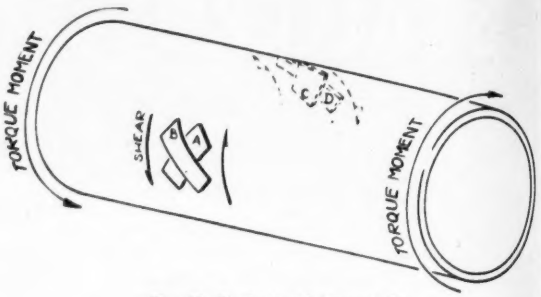


Fig. 13. Strain-gaged torque tube.

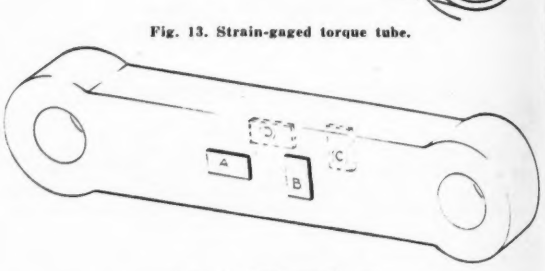
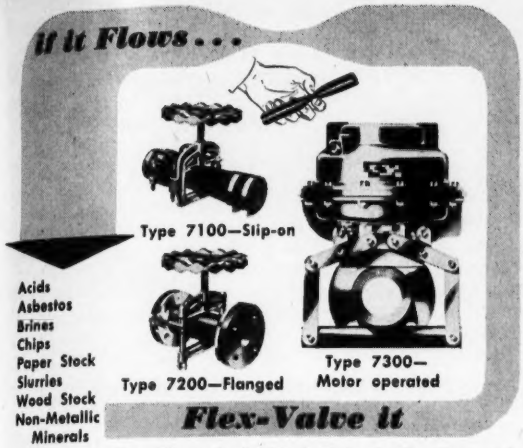


Fig. 14. Strain-gaged link.

Because of the desirability of high sensitivity, the maximum number of active gages were used in the bridge types described. It would not have been necessary to use more than two active gages to measure bending and shear. However, the reliability of an instrument indication for determining a stress or force is mainly dependent upon the output of the strain-gage bridge. In using the direct-reading d-c. strain-gage bridge, the instrumentation is often attenuated as much as one-third to prevent overloading the instrument. When amplifiers are used in conjunction with strain gages, a lower bridge output can be used but the magnitude and number of possible errors are multiplied. Given the desired range of instrument deflection, it is important that as much as possible of the deflection is due to the strain sensitivity of the bridge itself. This is comparable to what is known to the electronics engineer as "signal-to-noise ratio." We see that the basic requirement of the direct-reading d-c. strain-gage bridge—that it have sufficient strain-sensitivity to operate an indicating instrument without amplification of its output—is fundamental to the basic requirement of reliable strain-gage data.

Another inherent advantage of the direct-reading d-c. strain-gage bridge is the fact that lead wires and accompanying plugs and connectors are external to the bridge circuit. Systems using amplifiers may not have all four arms of the bridge in close proximity, necessitating lead wires and connectors within the wiring of the bridge. Temperature changes, lead-wire resistances, and changes in lead-wire resistance have much less effect upon the instrument indication when the leads are external to the bridge than when they are within it. The reliability and accuracy of a resistance calibration is much greater when made on a bridge without internal long leads. The reason for this is that a small lead resistance in series with a high calibration resistance has less effect than the same lead resistance in series with a strain gage of comparatively low resistance. Calibration errors as well as spurious strain readings are often caused by



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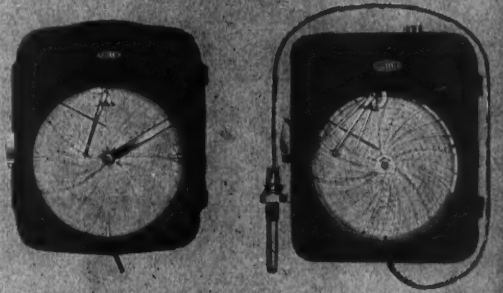

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leads connected between the elements of the bridges used in a test.

The maximum value of the bridge voltage is governed by the safe current the strain gages can handle without overheating. This is largely dependent upon the heat transfer qualities of the bonding and insulation materials. The maximum value of bridge current, V/R varies with individual strain gages and the particular installation. A maximum current of about 0.1 ampere using 120-ohm gages can usually be regarded as safe. There are exceptions, however, for in some cases the heat dissipation qualities of the test specimen will not permit as much as 12 volts on the bridge. Referring to Fig. 7 we see that a switch is provided which gives three selections of bridge voltage for a strain-gage channel. With proper design and use of strain-gage instrumentation, it should seldom be necessary to operate the strain-gage bridge at more than 6 volts.

PHOTOELECTRIC MEASUREMENT OF DUST

Continued from page 534

The light source operates at 75 percent of rated voltage, which is controlled by a variac in conjunction with a Sola constant-voltage transformer. The low-voltage operation prolongs the life of the light source and also makes the

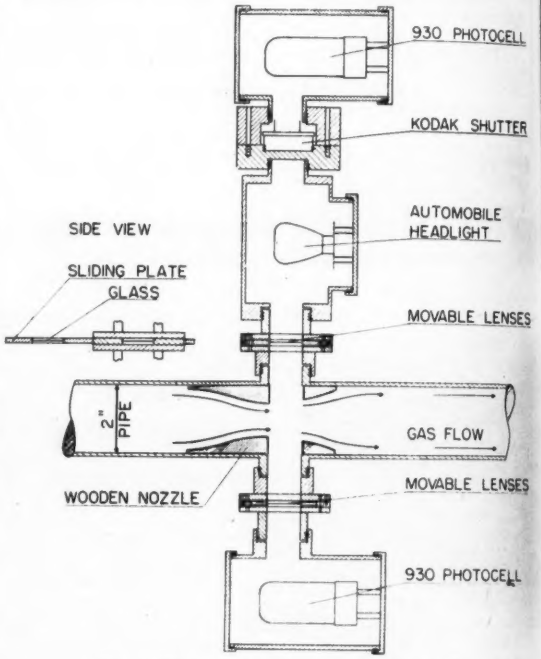

Fig. 3. Diagram of bridge-type smokemeter.

operation much more stable. However, even with these precautions, aging of the light source after 100 hours of operation produced instability in the light emission, which could not be eliminated by the bridge circuit. Although theoretically such elimination should be possible, the difference in phototube characteristics prevents complete cancellation.

A wooden venturi-type nozzle in the sampling tube prevents excessive collection of dust on the lens because of the converging flow lines and reduced pressure affected by the venturi section. Without this nozzle, the lens collection was so rapid that readings could not be made. However, when the nozzle is used, many hours of continual operation are possible without cleaning the lenses.

SAMPLING CHARACTERISTICS

Some measurements were taken to find the effect of the sampling velocity on the indication. Although a true loading indication should be obtained when the duct and sampling velocities are equal, the method of measurement,

Continued on page 578

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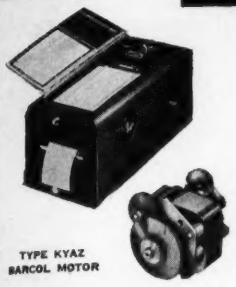

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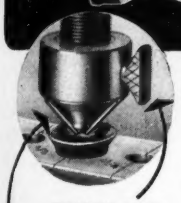

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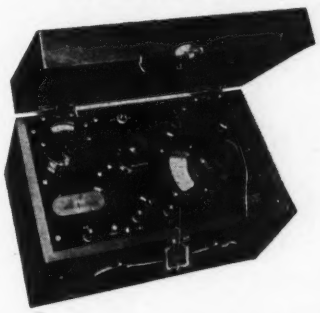

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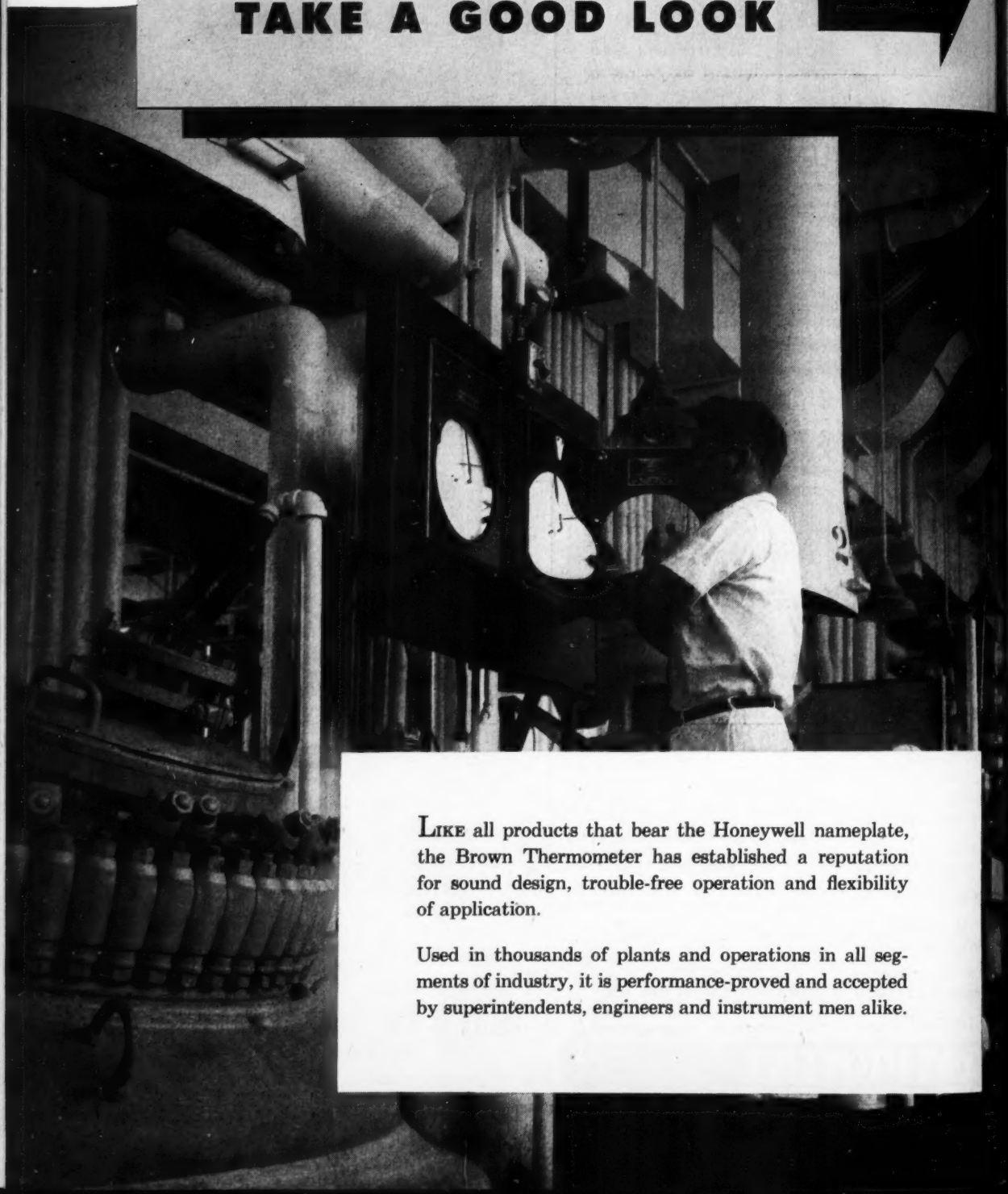

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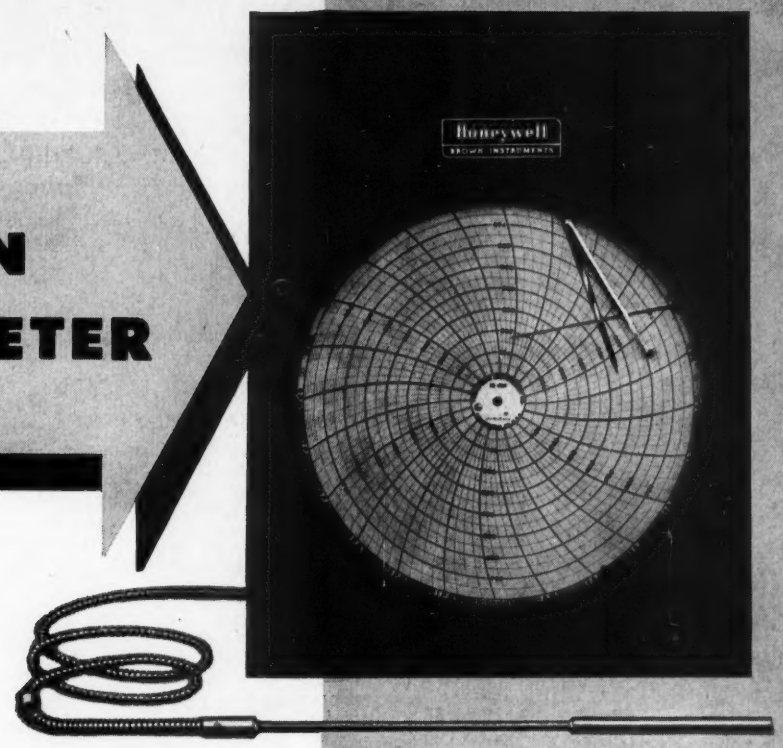

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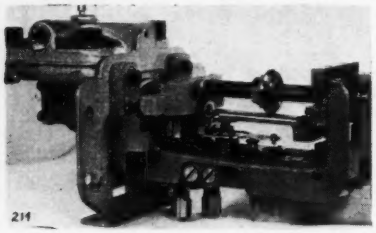
Pneumatic Flow Transmitter

New "Differential Converter" is a lightweight transmitter designed for sensitive measurement and control of fluid flows. Converter has a continuously adjustable range from 0-20 to 0-200 in. water (differential pressure) with no change of parts. Field calibration of any range is possible by use of scale-type weights which eliminate need



for water column. Operating on pneumatic-balance principle without mercury, the differential pressure due to fluid flow at metering orifice is continuously balanced by pneumatic pressure, which is connected to a recording or controlling instrument. Fast speed of response to rapid changes in flow is prime feature claimed. Forged body is offered with 750- or 1500-psi. rating in stainless or carbon steel. Volume displacement in meter is so small that seal pots or condensing chambers can be eliminated in most installations.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrom Aves., Philadelphia* 44, *Penn.*

Mention No. 501 when filling out card.

Portable Air-meter

New battery-operated air-meter measures air velocities from 0 to 4000 ft. per min. and static air-pressures from 0 to 4 in. water. Instrument has two scales for air velocity measurement; low range from 0 to 750 ft. per min., high range from 750 to 4000 ft. per min. Probe-mounted noble-metal thermopile is placed in airstream whose velocity is measured. Static pressure is meas-

ured by use of pressure attachment on probe. Device is not affected by length of cable or sudden temperature variations. Instrument lag is less than one second. Weight is 11 lbs.—*Hastings Instrument Co., Inc., Super Highway at Pine Ave., Hampton* 10, *Va.*

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Moisture Tester

New "Model 8008 Moisturonic" tester measures moisture content of lumber, wood, plaster, and other materials of varying textures. Portable instrument has range from 2,000 ohms to 20,000 megohms, and large scale. Measures resistance between electrode probes in-

serted into material to be measured. Available with scale calibrated for use with lumber, wood, plaster, and wood products, or with linear graduations for use with materials for which no calibrations have been determined. Available as either battery operated or 115-v. 60-cycles a-c. operated.—*Tagliabue Instrument Div., Weston Electrical Instrument Corp.*, 614 *Frelinghuysen Ave., Newark* 5, *N. J.*

Mention No. 503 when filling out card.

Multi-station Thermocouple Gage

New "Type TG-09" thermocouple pressure gage is available with 2, 3, 4, 5, or 6 stations, all reading on single indicator. Range is from a few microns to one millimeter Hg. Gage operates from 115-v. 60-cycle circuits. Also available is "Type TG-08" single-station thermocouple gage operating from two flashlight dry cells. Sensitive element is thermocouple junction to which heat is supplied at constant rate by voltage-regulator circuit. Gage tube may be mounted vertically and plugged into control cabinet or it may be used with cord several hundred feet long.—*Vacuum Equipment Dep't, Distillation Products Industries, Rochester* 3, *N. Y.*

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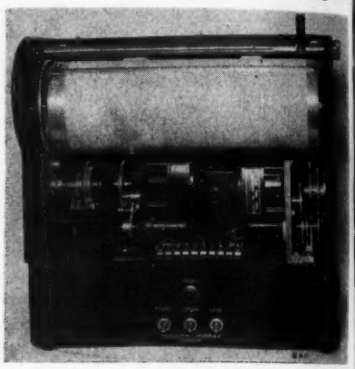
X-Y Recorder

New "MD-2" portable X-Y strip-chart recorder automatically plots simultaneous relationship between any two variables that can be made to actuate "Microformers." Any standard Baldwin "Microformer" strain follower may be used. "Microformers" are miniature variable transformers having us-



able core movements of 0.120 in. Displacement of core upsets self-balancing bridge. Unbalanced signal is amplified electronically and drives servomotor which repositions core and operates the recorder drum or stylus. Sensing "Microformer" core movements of 0.03 in. and 0.06 in. produce full-scale (10-in.) displacement of stylus; core movements of 0.03 in., 0.06 in., and 0.120 in. produce drum rotation of 10 in. Movement of external "Microformer" core recorded to accuracy within 0.2 percent recorder scale. Recorder weighs 50 lbs. —*Baldwin-Lima-Hamilton Corp., Phila.* 42, *Pa.*

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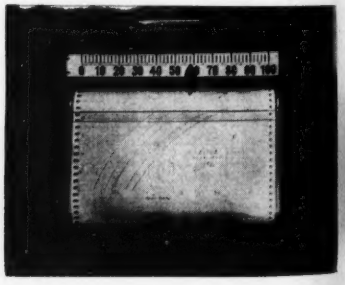
X-Y Recorder

New "ElectroniK" function plotter incorporates two measuring systems; one actuates recorder pen, the other motivates instrument chart. Chart is driven up and down in response to changes in one variable simultaneously with movement of pen in response to changes in second variable; resulting in curve which continuously evaluates one variable in terms of second variable. Interdependent nonlinear variables are



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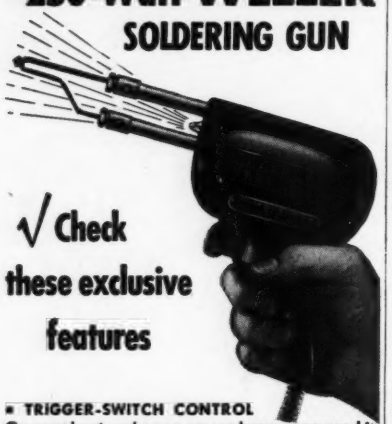

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plotted easily. By using function plotter, measurements can be compiled and curve plotted automatically. Measurements over entire curve are continuous; no interpolation needed to complete data between points of measurement.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Penna.*

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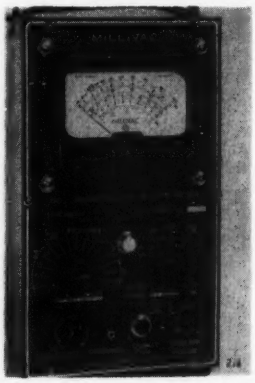
D-c. Micromicroammeter

New "MV-11A" electronic ammeter has ranges from 1 micromicroampere to 10 amperes with small voltage drops across measuring shunts. D-c.



voltage input is modulated on 120-cycle signal, which is amplified, rectified, and metered. Operates from 115-v. a-c. supply.—*Millivac Instrument Corp., Box 3027, New Haven, Conn.*

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Portable pH Tester

New battery-operated pH tester uses polyethylene probe unit which combines calomel and glass electrodes with sample holder. Sample volume required is 0.5 ml. Electrometer tube, switch, and

input connector are sealed from high-humidity conditions. Scale is marked 2 to 12 pH. Adjustment gives readings from 0 to 14 pH. Accuracy is 0.1 pH. Instrument is supplied with plastic tubes of buffer and KCl solutions. Bakelite case is 3 x 5.88 x 2.5 in. Weight is 3 lbs.—*Analytical Measurements, Inc., 585 Main St., Chatham, N. J.*

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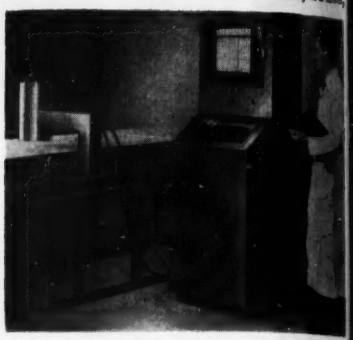
Beta-ray Thickness Gage

New beta-ray gage records continuously variations in weight per unit area or thickness of sheet material on production line. Steel, aluminum, brass,



rubber, plastics, and coated textiles can be gaged to a few millionths of an inch. Material being measured is run through gap between source of beta radiation and radiation detector. Standardizes automatically for drifts and errors.—*Industrial Nucleonics Corp., 1205 Chesapeake Ave., Columbus 12, Ohio.*

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F-m. Oscillator with Markers

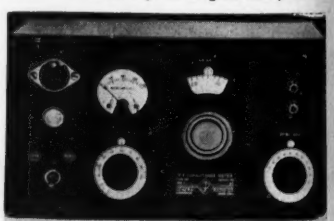
New "Marka-Sweep" f-m. oscillator has built-in crystal markers at 1, 2, 5, 10, 15, and 20 mc. Two wide bands of

50 kc. to 10 mc. and 50 kc. to 20 mc. are selected by switch. Output of 0.3 v. at 72 ohms has either continuous or switch-type attenuator.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 510 when filling out card.

Capacitance Tester

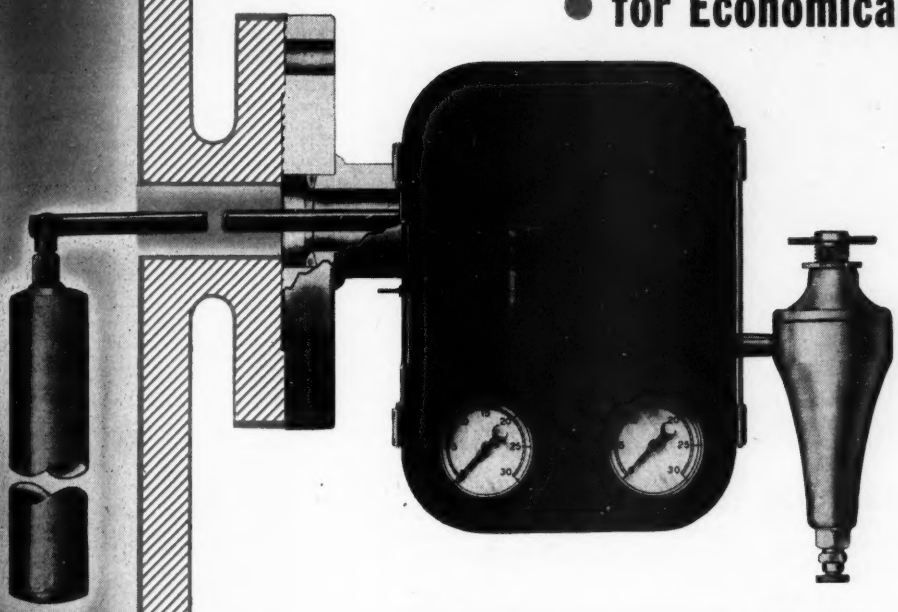
New "Type 1612-AL" capacitance tester measures capacitance from a few hundredths of a uuf. to 100 uuf. by substitution method in circuit resonated at 1 mc. Ranges are 0 to 10 uuf. and 0 to 100 uuf. Instrument has built-in 1-mc. oscillator and resonance indicator. Accuracy is 5 percent, or 0.05

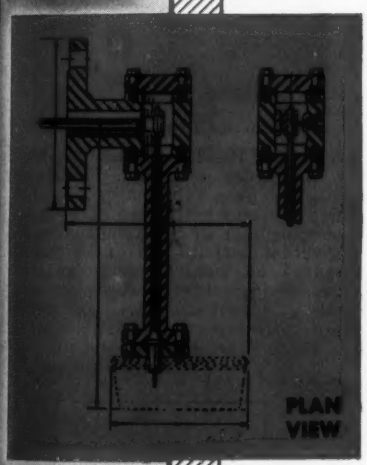


The NEW BS&B "Climax" LIQUID LEVEL CONTROLLER

TYPE 889

Internal Side-Flange Mounted
- for Corrosive Conditions
- for Economical Installation





Here's a level controller designed for mounting on a flanged vessel nozzle with the displacement element operating within the vessel itself. It offers a *more economical* installation than an external mounting. Use the new Type 889 where external cage mountings are impractical due to clogging or vapor-locking of equalizing lines.

Torque tube, tube assembly, connecting parts, pilot and regulator are same as the famed new BS&B "Climax" Type 888. Standard size available in 4" ASA flange series. Larger flanges or special connections available on request.

Displacement elements up to 120 inches can be furnished. Write today for new catalog, specifications, prices.

BLACK, SIVALLS & BRYSON, INC.
Climax Controls Division
Adv. Dept. Rm. 54V 7502 East 12th Street
Kansas City 3, Missouri

BS&B

"Climax" Type 889
INTERNAL SIDE-FLANGE MOUNTED
LIQUID LEVEL CONTROLLER

NEW *Berkeley* DECIMAL SCALERS!

GM OR SCINTILLATION COUNTING*

SINGLE "H.V." CONTROL

SMALL — LIGHTWEIGHT

POSITIVE OR NEGATIVE "H.V." SUPPLY*

ELECTRONIC SCALE-OF-100

DIRECT READING

PREDETERMINED COUNT*

LOW COST

MODEL 100

***Berkeley* Basic Scaler**

SINGLE HI-VOLTAGE CONTROL simplifies operation, prevents inadvertent over voltaging of GM tubes. Single continuous control from 0 to 2,500 volts.

TRUE DECIMAL PRESENTATION for easy reading. No interpolation, no lights to add. Results are presented in direct reading form on illuminated panels of the two electronic counting units. A 6-place mechanical register extends total capacity to 99,999,999. Selectable electronic scale of 10 or 100.

SMALL, LIGHTWEIGHT for easy portability. Weighs only 18 lbs.; measures 9¾" x 10¾" x 14½". Baked enamel finish permits easy decontamination.

ACCESSORY OUTLETS are provided for external clock, timer, loudspeaker, or output pulse per count to drive count rate meter or counting rate computer and recorder.

***MODEL 110**

***Berkeley* Universal Scaler**

This versatile scaler has all the features of the Model 100, plus:

POSITIVE OR NEGATIVE HI-VOLTAGE SUPPLY, selectable by simple internal switch, permits use with either GM or scintillation detectors.

BUILT-IN PREDETERMINED COUNTER provides presettable scaling factors of 100, 200, 400, 1,000, 2,000, 4,000, 10,000 and 20,000.

LOW COST:

The Model 100, produced in quantity, provides a basic Geiger-Muller Scaler at minimum cost. **Price $330**

The Model 110, with its added features, offers maximum flexibility in meeting your every counting need. **Price $425**

For complete information, write for bulletin 100-I

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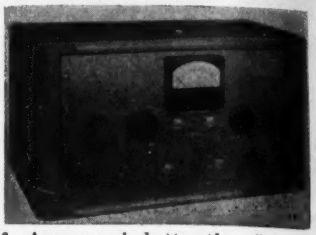
uuf. below 1 uuf.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 511 when filling out card.

Capacitance Tester

New direct-reading a-c. operated tester measures small values of direct capacitance on a 4-in. logarithmic scale. Scale ranges are 0.1, 1.0, 10, and 100



uuf. Accuracy is better than 5 percent. Calibration is by built-in standard. Measurements are made at 500 kc. Power factor is not measured.—*MacLeod and Hanopol, Inc., 10 Joiner St., Charlestown 29, Mass.*

Mention No. 512 when filling out card.

Grating Monochromator

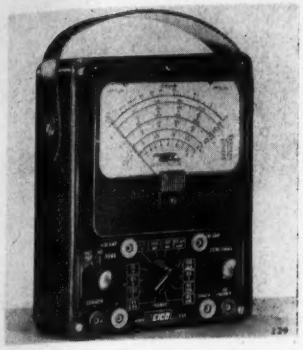
New grating monochromator uses mirror optics to provide monochromatic radiation from ultraviolet (2000A) to infrared (6 microns) without changing components. Spectral purity is equal to or better than prism-type double mono-

chromator. Resolution and dispersion for first-order spectrum depends on number of lines ruled on grating. Amplifier operates with light chopper and photomultiplier or photoconductive cell to give d-c. output. Sensitive elements, prepared on small rectangular glass pieces, are provided with contact electrodes and used behind an exit slit.—*Baird Associates Inc., 33 University Rd., Cambridge, Mass.*

Mention No. 513 when filling out card.

Portable Multimeter

New "Model 555" multimeter has 4.5-in. indicator and 50-ua. movement, which gives input impedance of 20,000 ohms per v. D-c. voltage ranges are: 0-2.5, 10, 50, 250, 1000, 5000; a-c. voltages same as d-c. at 1000 ohms per v. D-c. resistance: Rxl, x100, x10000. D-c. current: 0-100 ua., 10 ma., 100 ma., 500

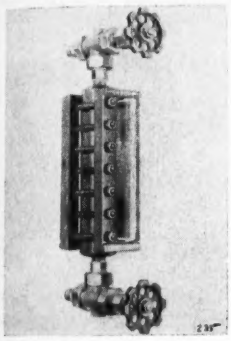


ma., 10 a. D-c. accuracy is 3 percent of scale; a-c. is 5 percent of scale.—*Electronic Instrument Co., Inc.*, 276 *Newport St., Brooklyn* 12, *N. Y.*

Mention No. 514 when filling out card.

Frost-proof Level Gage

New "Series RLF-10 and TLF" non-frosting large-chamber gages prevent frost from forming over vision slot for level reading of low-temperature



and low-boiling-point liquids. Large area of meniscus results in less turbulence. Patented gage-glass extension is transparent unit extending from gage glass and projecting beyond cover bolts so that frost cannot build up over vision slot.—*Ferguson Gage & Valve Co.*, 80 *Fellsway, Somerville*, 45, *Mass.*

Mention No. 515 when filling out card.

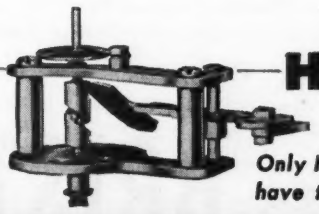
Microphotometer

New photomultiplier microphotometer measures and compares light intensities from 20 micromicrolumens to 20 lumens at selected wavelengths. Me-

ILLUMINATED DIAL GAGES ARE MUCH EASIER TO READ

- illuminated dial with black light just like airplane or automobile panel instruments for better visibility without glare
- also available with white light and with black or white dials
- ideal for symmetrical panel layouts
- dial sizes 4½", 6" or 8½"—all standard pressure ranges

Write for complete information



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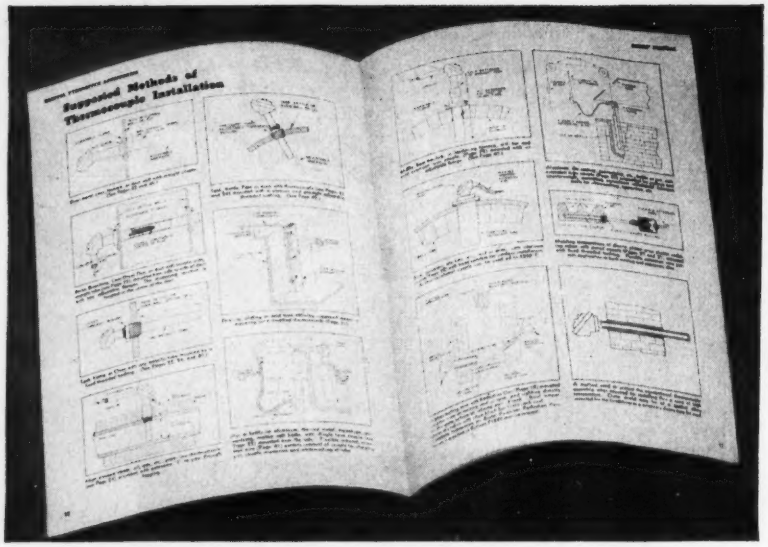

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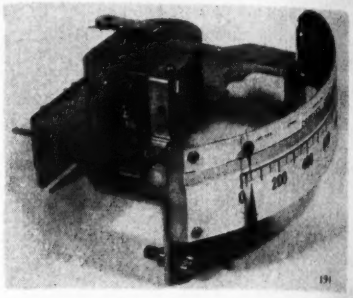
ter indicates percent transmission, density, and photocurrent microamperes directly without correction factors. Outlet on panel provides 10 mv. at 100 microamperes for operation of commercial recorder. Operates with 60-cps. a-c. supply. Current gain of 100,000 with negligible drift is provided by electrometer subminiature-tube circuit. —*American Instrument Co., Silver Spring, Md.*

Mention No. 516 when filling out card.

Indicating Millivoltmeter

New indicating millivoltmeter contains a galvanometer unit; is comparatively free from effects of vibration and from varying lengths of extension wires. It can be actuated by thermocouples



and Radiamatic pyrometers, tachometers, resistance thermometers or any source of millivoltage. Instrument has plug-in inter-changeable galvanometer in upper compartment. Calibrated measuring system, scale, pointer and mirror are said to be completely protected.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., 4482 Wayne Ave., Philadelphia 44, Penna.*

Mention No. 517 when filling out card.

AM Frequency Monitor

New "Type BW-11A" monitor will continuously and directly indicate, in cps., magnitude and direction of any departure of transmitter frequency from its assigned channel in range of 500 to 2000 kc. It reveals deviation range, readable to 1 cps., of plus or minus 30 cps. with an accuracy of 10 ppm. Stability under normal operating conditions is better than 1 ppm. Wide variations in tube characteristics and line voltage cause negligible error in deviation indications, maker states. A warning lamp indicates failure of either

Responsible positions in a diversified program of research on the development and application of modern physical instrumentation to an expanding Gulf Coast chemical industry are open to interested physical chemists, chemists, and physicists. A broad program of investigation will include ultraviolet and infrared spectrometry, mass spectrometry, refractometry, potentiometric devices, thermal conductivity, dielectric constant, etc. Conventional instruments are being evaluated and modified, and new and original ones developed. These positions are in the research department and are closely integrated with the development of new products and processes. They will require originality and ingenuity. Experience desirable, but not essential. Salary commensurate with qualifications.
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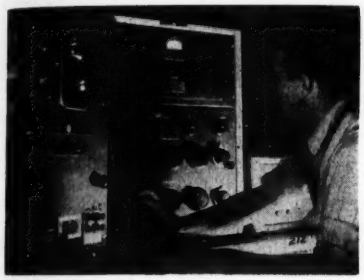
transmitter carrier or monitor crystal oscillator. RF pickup can be obtained either by direct connection to transmitter or by short length of wire attached to input terminals. Over-all dimensions 19 × 15.75 × 9.63 in.; weight 60 lbs.—*RCA Engineering Products Dept., Radio Corp. of America, Camden, N. J.*

Mention No. 518 when filling out card.

Feeder Voltage Regulators

New feeder voltage regulators are at least 99 percent accurate regardless of changes in temperature or load. New controls are designed to meet ASA



requirements for Class 1 accuracy; they allow feeders to carry heavier loads for greater distances, it is claimed.—*Transformer and Allied Products Divs., General Electric Co., Schenectady 5, N. Y.*

Mention No. 519 when filling out card.

Magnetic Memory

New "Static Magnetic Memory" uses saturable reactors with cores of Permanorm 5000Z to store, delay, and count pulse-type information. Core

Experienced Instrument Engineer

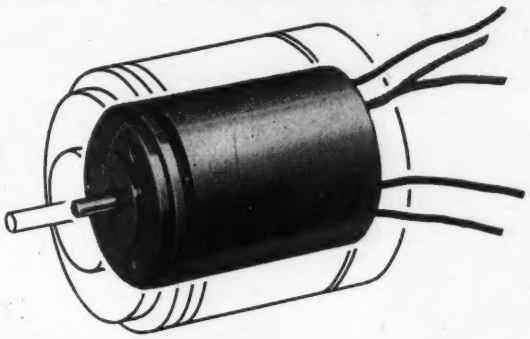
Vacancy for a permanent appointment as instrument engineer with this company exists for a man between 25 and 35 years of age and A1 medical category. He should be able to select proper equipment for new jobs also interpret results and calculate correction factors of instruments. He must have experience and ability to organize instrument maintenance and carry out normal repairs.

Applications should be made to Canada and Dominion Sugar Co. Ltd., P. O. Box 490, Montreal, Quebec, in envelopes marked "Instrument Engineer."

ECLIPSE-PIONEER

Announces the New Line of

PYGMY SYNCHROS



Size of pygmy as compared to AY-200 series outline

Eclipse-Pioneer has added a tiny new member to its great family of famous Autosyn* synchros. It's the new AY-500 series, a precision-built pygmy weighing only 1¾ oz. while scaling only 1.278″ long and .937″ in diameter (the same diameter, incidentally, as a twenty-five cent piece). Its accuracy and dependability are assured, thanks to Eclipse-Pioneer's 17 years of experience and leadership in the development of high precision synchros for aircraft, marine and industrial applications. For more detailed information on the AY-500 and other E-P Autosyns, such as the remarkably accurate AY-200 series (guaranteed accuracy to within 15 minutes on all production units), please write direct to Eclipse-Pioneer, Teterboro, N. J.

*REG. TRADE MARK BENDIX AVIATION CORPORATION

LOOK FOR THE PIONEER MARK OF QUALITY
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Typical Performance Characteristics

	One AY-201-3 Driving		One AY-500-3 Driving
	One AY-500-3 Control Transformer	Two AY-500-3 Control Transformer	One AY-500-3 Control Transformer
INPUT			
Voltage	26-volts, single-phase	26-volts, single-phase	26-volts, single-phase
Frequency	400 cycles	400 cycles	400 cycles
Current	88 milliamperes	110 milliamperes	55 milliamperes
Power	0.8 watts	1.2 watts	0.9 watts
Impedance	105+j280 ohms	100+j220 ohms	290+j370 ohms
OUTPUT			
Voltage Max. (rotor output)	17.9 volts	16.2 volts	14.1 volts
Voltage at null	40 millivolts	40 millivolts	40 millivolts
Sensitivity	310 millivolts/degree	280 millivolts/degree	245 millivolts/degree
Voltage phase shift	23 degrees	26 degrees	44 degrees
System accuracy (max. possible spread)	0.6 degrees	0.6 degrees	0.75 degrees

Other E-P precision components for servo mechanism and computing equipment:
Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies • remote indicating-transmitting systems and special purpose electron tubes.

For detailed information, write to Dept. A

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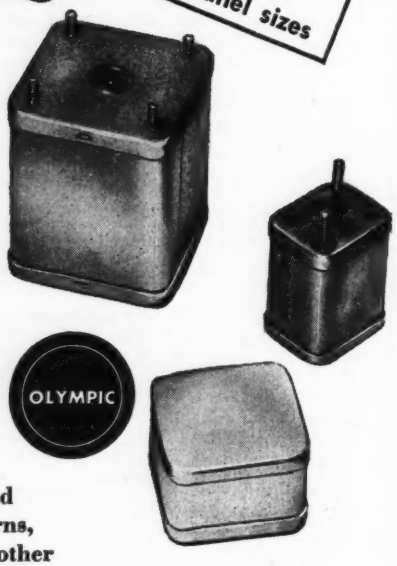

Case bodies fabricated to any length required. Hot tin dipped to your specifications. Covers and cases modified with hole patterns, cut-outs, mounting brackets or other special requirements.

Facilities available for fabrication of sub-assemblies.

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of reactor is saturated or unsaturated by pulse signal, making reactor act as open or closed switch. Saturation condition persists after pulse, permitting pulse storage without power. Counts or circulates any configuration of pulses.—*Alden Products Co.*, 117 *N. Main St., Brockton* 64, *Mass.*

Mention No. 520 when filling out card.

Automatic Batch Counter

New "Monitor" automatic batch counter counts batch quantities at high speed. Batch-control switch operates automatically at completion of each

count. Instrument furnished with ranges from 1 to 99, 999, 9999, or 99999. Any desired batch quantity within range can be selected by dial pointers. Operates on 115 v. 25 to 60 cycles.—*Production Instrument Co.*, 702 *W. Jackson Blvd., Chicago* 6, *Ill.*

Mention No. 521 when filling out card.

Pyrometer Controllers

New "Simplytrol" pyrometer controllers have large 4.5-in. indicator. Contact relays for control action are interchangeable for different temperature ranges. "Series 4540" has limit-control contacts which make when pre-

INSTRUMENT ENGINEER

With background and desire sufficient to handle electrical instrument department-potentiometer controls or recorders, bridges and/or galvanometers and servo-mechanisms. Must be capable of initiating designs and handling developments and application. Give experience, education, age, references and salary expected or received. Replies confidential. Location-West. Box 196, Instruments Publishing Company, 921 Ridge Ave., Pittsburgh 12, Pa.

set temperature is reached. "Series 4530" has limit control and automatic on-off control to maintain preset temperature.—*Assembly Products, Inc., Chagrin Falls, Ohio.*

Mention No. 522 when filling out card.

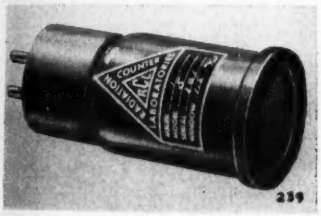
Event Counter

New "Type-M1731 Eventometer" measures number of cycles occuring in a time interval. Number counted is displayed on 5 columns of lights. Specifications include: input signal frequency range from 10 cps. to 150,000 cps.; accuracy of plus-or-minus one cycle; input signal amplitude from 0.5 to 100 v. rms.; 60-cps. a-c. power.—*Walkirt Co., 5808 Marilyn Ave., Culver City, Calif.*

Mention No. 523 when filling out card.

Radioactivity Counter

New "Mark 1, Model 5" fusion-seal mica-window counter has thin mica window for counting beta rays. Samples can be placed within 1/32 in. of window. Can be used with Tracerlab "TGC-1 or TGC-2" Geiger counters. Specifications include threshold of 1200



WANTED

Technical Correspondent
(Pyrometer Experience)

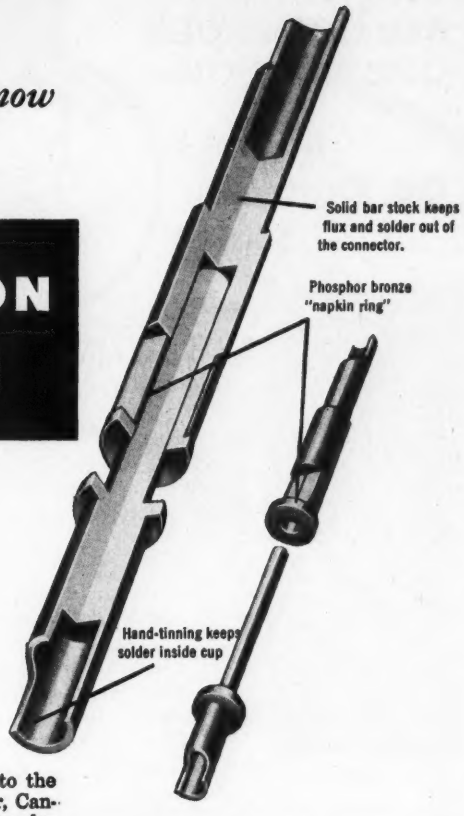
Unusual opportunity for lifetime position to proper party between age of 25 and 45. College education essential. Must have thorough knowledge of pyrometers and accessories and be capable of figuring and submitting quotations and handling technical letters and telephone inquiries. All replies will be held strictly confidential. Salary open. This is an old established firm located in Midwest United States. Give full particulars concerning qualifications in first letter.

Address reply to Box 197, Instruments Publishing Co., 921 Ridge Ave., Pittsburgh 12, Penna.

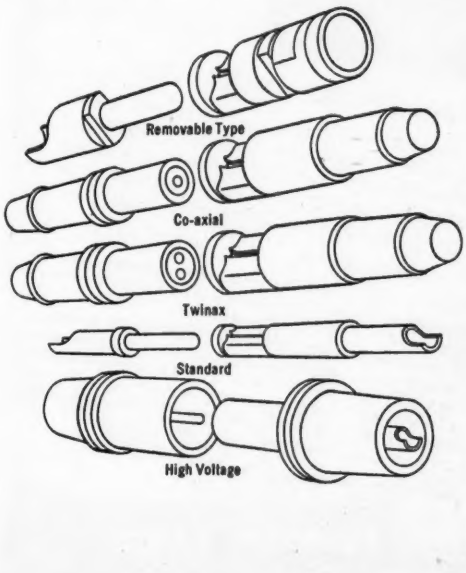
Here's why those in the know demand–

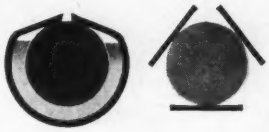
CANNON PLUGS

superior contact design


Solid bar stock keeps flux and solder out of the connector.
Phosphor bronze "napkin ring"
Hand-tinning keeps solder inside cup

Because the contact is the key to the success of any electric connector, Cannon has always applied the highest order of skill and care to this all-important detail. Cannon pin and socket contacts are all precision machined from solid bar stock. Silver or gold plating maintains high conductivity after years of constant use. Phosphor bronze "napkin ring" of the socket keeps pressure on large areas of heavy metal, preventing current loss. There are no thin metal tangent contact points in Cannon contacts. (See below). Solder cups are carefully tinned by hand to keep the solder inside the cup. Cannon socket contacts are full floating to assure perfect alignment. You'll find these design features throughout the great variety of precision contacts used in all Cannon connectors. For real value demand Cannon.





Cannon design (above left) makes contact on large, heavy metal surfaces. Current is not carried through spring section. In Cannon Connectors there are no thin metal tangent contact points, like the design shown at right.

CANNON ELECTRIC

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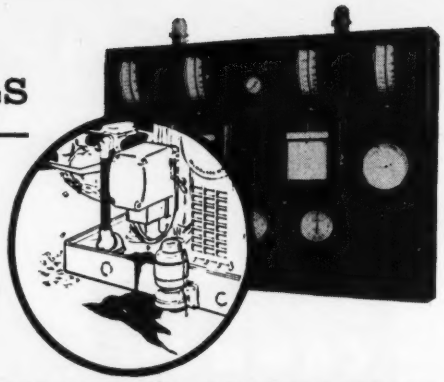
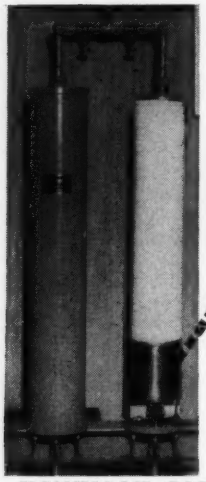
Water!
Oil Sludge!
Scale?





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PROVIDES *Three Way* PROTECTION

- **COOLING**—Condenser is the HEART of the CONDENSIFILTER —cools air to within less than 5° of cooling water temp.—lowers dew point.
- **AUTOMATIC BLOW DOWN**—Specially designed to eliminate daily attention—practically no maintenance cost.
- **FILTERING**—5 concentric brass baskets in parallel—each wrapped with seven layers of canton flannel—provides over 16 sq. ft. of filter surface area.

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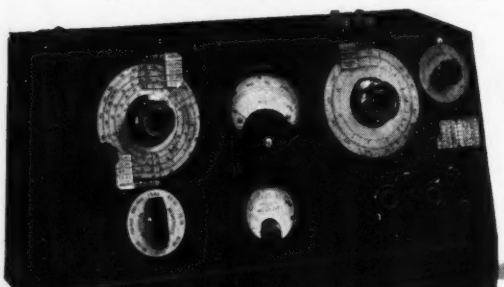


The Q METER
TYPE 160-A

ACCURATE • DEPENDABLE • VERSATILE

For the measurement of Q, inductance, and capacitance, the 160-A Q-Meter is the universal choice of radio and electronics engineers. Its wide frequency coverage from 50 kc. to 75 mc. is an outstanding feature which makes possible the accurate and rapid evaluation of components and insulating materials at the actual operating frequency.

SPECIFICATIONS

OSCILLATOR FREQUENCY RANGE: 50 kc. to 75 mc. 8 self contained ranges.
OSCILLATOR FREQUENCY ACCURACY: ±1%, 50 kc.-50 mc. ±3%, 50 mc.-75 mc.
Q-MEASUREMENT RANGE: Directly calibrated in Q, 20 250. "Multiply-Q-By" Meter calibrated at intervals from x1 to x2, and also at x2.5, extending Q-range to 625.
Q-MEASUREMENT ACCURACY: Approximately 5% for direct reading measurement, for frequencies up to 30 mc. Accuracy less at higher frequencies.
CAPACITANCE CALIBRATION RANGE: Main capacitor section 30-450 mmf, accuracy 1% or 1 mmf. whichever is greater. Vernier capacitor section +3 mmf., zero, -3 mmf. calibrated in 0.1 mmf. steps. Accuracy ±0.1 mmf.

Write for literature containing further details

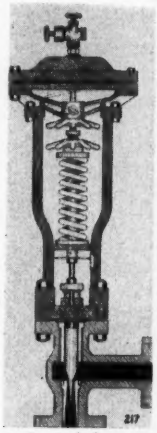
BOONTON RADIO Corporation
BOONTON N.J. U.S.A.

v., plateau of 200 v., 4-prong tube base, and height of 1.1 in.—*Radiation Counter Laboratories*, 1844 *W.* 21*st St., Chicago* 8, *Ill.*

Mention No. 524 when filling out card.

Stainless-steel Valve

New "Type-V10" line of flow-regulating valves is designed to handle steam and water at high pressure drops, and especially flashing condensate. Internal parts of valve, seat, disk and long-guide sleeve, are made

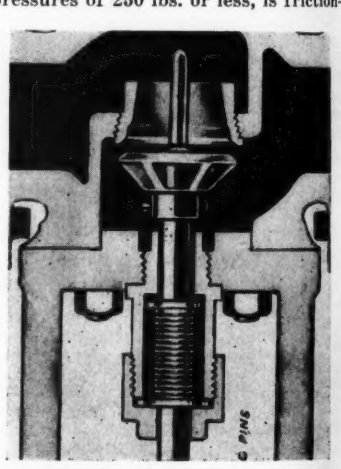


of heat-treated stainless steel. Exclusive scroll inlet and gradually-expanded straight outlet eliminate direct impingement and resulting corrosion-erosion effects. Valves are supplied in 7 pipe sizes: 1 to 4 in., and in 150 to 600 psi. standards. 900-1500 and 2500 psi. standards also available.—*The Swartwout Co.*, 18511 *Euclid Ave., Cleveland* 12, *Ohio.*

Mention No. 525 when filling out card.

Packless Reducing Valves

New packless construction in pilot-operated and direct-operated reducing valves in sizes 0.5 through 3-in., for pressures of 250 lbs. or less, is friction-



less, eliminating sticking stems and assuring steady regulation to ounces. No change made in over-all dimensions of standard valves.—*C. E. Squires Co.*, 18502 *Syracuse Ave., Cleveland* 10, *Ohio.*

Mention No. 526 when filling out card.

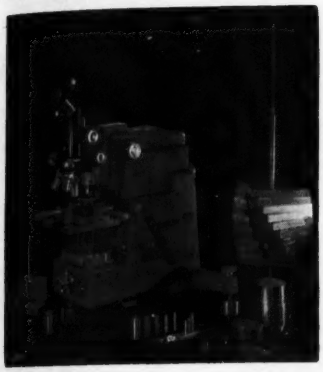
Air-line Drain Valve

New line of diaphragm-operated valves for automatic removal of contaminants and precipitates from compressed air lines and systems includes automatic separators and drains. When air line is not in use diaphragm is forced down by back pressure and seals sump bottom. As air is used diaphragm raises shaft, seals bottom of middle chamber, opens bottom of sump, and blasts out contamination.—*Wilkerson Corp., 1749 So. Broadway, Denver, Colo.*

Mention No. 527 when filling out card.

Micro-hardness Tester

New improved "Kentron" micro-hardness tester makes Knoop or Vickers hardness tests on metals, fine wire, precision parts, plastics, glass, paint,



ceramics, etc. Applies dead-weight loads from 1 to 10,000 grams. Test specimen slides underneath high-powered objectives without disturbing focus. Vise index locates impressions readily any time after testing.—*Kent Cliff Laboratories, Peekskill, N. Y.*

Mention No. 528 when filling out card.

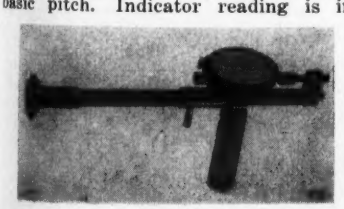
Dry Hardness Tester

New "No. 673" dry hardness tester measures sand core hardness. Tester is pressed flat on core, knife is rotated 90 deg., and hardness read from 0 to 100 circular dial. Instrument also reads scratch and indentation hardness.—*Harry W. Dietert Co., 9330 Roselawn Ave., Detroit 4, Mich.*

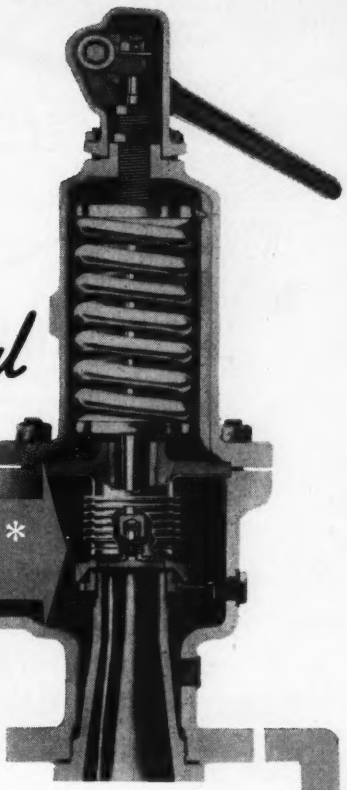
Mention No. 529 when filling out card.

Internal Thread Comparator

New internal thread comparator measures from pitch line of any one thread in "nut" to pitch line of two threads lying diametrically opposite. When set to basic ring gage, comparator gives plus or minus deviations from basic pitch. Indicator reading is in



meet the newest member of the *FarriSeal* family



BalanSeal*

IT SAVED $75,000 IN PIPING WITH A $5,000 VALVE INVESTMENT**

Pioneered by Farris Engineering Corp., embodying advanced engineering technics, *and absolutely unique*—although it is now being imitated—the patented BalanSeal is ideally suited for use wherever a collecting system is required for a series of safety-relief valves. It permits a higher downstream pressure—and consequently, smaller piping. Yes! The cost of a BalanSeal valve installation is a mere fraction of the savings effected in down-stream piping. (**In one case, a cost reduction of $75,000 resulted from a $5,000 investment in BalanSeal Valves.)

In BalanSeal, the sole force opposing the opening of the valve is the spring. Downstream back pressure, static or surge, cannot act on the disc and has absolutely no effect on the relieving point.

BalanSeal is the ultimate in safety-relief valve design and construction. The bellows, which also distinguishes the FarriSeal design, is so proportioned as to eliminate any unbalanced forces on the valve disc—which is perfectly balanced on its seat at the set pressure. Like all other FarriSeal Valves, perfect protection is provided for guide, stem and spring by completely isolating these parts from the lading fluid.

Get the facts on the revolutionary BalanSeal Safety Relief Valve. Find out how you can cut installation costs to the bone, step up operating profits. Write for Bulletin No. 52B—it will pay off in ASSURED safety and installation economy.

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SAFETY and RELIEF VALVES
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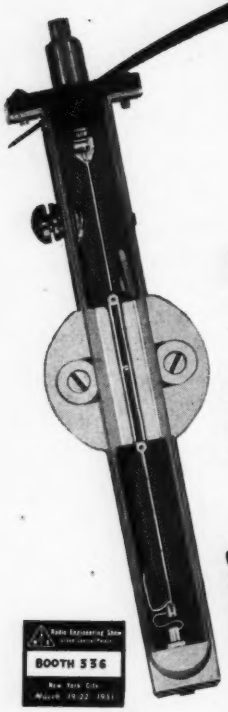
7676 436 Commercial Avenue Palisades Park, N. J.



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Heiland galvanometers are available in natural frequencies ranging from 32 cycles per second to 4700 cycles per second. All galvanometers are electromagnetically damped with exception of those having natural frequencies above 450 cycles per second; these are fluid damped. Permanent magnet assemblies are available for mounting 2, 6, and 12 Heiland galvanometers.

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tens of thousandths. Has a range of plus or minus 0.003 in.—*Rimat Machine Tool Co., Glendale 1, Calif.*

Mention No. 530 when filling out card.

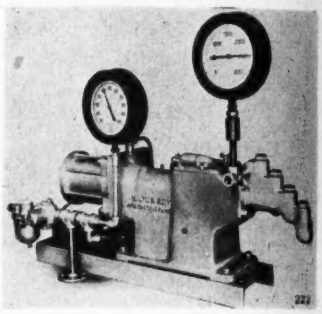
Concrete-beam Tester

New gage reads flexural strength of concrete-beam specimens having 6 x 6 in. cross-section and 18-in. span. One division on dial indicates applied load of 120 lbs., which corresponds to flexural strength (modulus of rupture) of 10 psi. Maximum flexural-strength capacity is 1250 psi. Total weight is 19½ lbs. Molds for casting 6 x 6 x 21 and 6 x 6 x 36-in. specimens can be collapsed for transportation.—*American Instrument Co., Inc., Silver Spring, Md.*

Mention No. 531 when filling out card.

Hydrostatic Pressure Generator

New "aiROYmetric" pressure generator develops hydrostatic test pressures up to 25,000 psi., using ordinary plant air supply in pump cylinder. Individual units custom made for applications between 25 and 25,000 psi. Capacities range from 4 to 405 gph. When a balance is reached between air pressure and corresponding hydrostatic test pressure, pump automatically stops. Double-ball check-liquid ends are nonclogging and self-cleaning—*Milton Roy Company, 1302 E. Mermaid Lane, Philadelphia 18, Penna.*

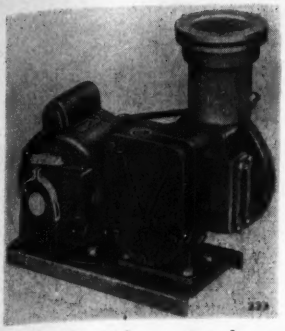


Mention No. 532 when filling out card.

Small Vacuum Pump

New "Model CVM 3153" compound vacuum pump employs oil-sealed pumping system and has free-air displacement of 2 cu. ft. per min. Designed for

WANTED—Sales Engineers and Service Engineers for large industrial instrument manufacturer. Prefer Mechanical, Electrical or Chemical Engineers with few years industrial experience. Fine opportunity for young engineers with sales or service aptitudes to connect with one of the fastest growing industrial instrument companies in the United States. Locations: Seattle, Washington; Detroit, Michigan; Charlotte, N. C.; and New York City. In addition to the above we desire services of two Sales Engineers who will be located at our factory for an indefinite period of time but will eventually be placed in large industrial cities of the United States. For the latter positions we desire men who will be flexible in regard to transfers. Exceptional opportunities for these two men who are willing to be sent on assignment anywhere in the United States. Box 198, Instruments Publishing Co., 921 Ridge Ave., Pittsburgh 12, Pa.

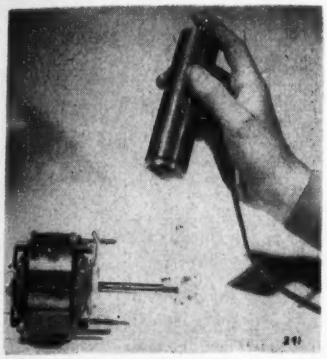


portability, the ¼-hp. motor, base, and pump, weigh 70 lbs. Produces McLeod-gage absolute pressure readings of 0.1 micron or better.—*Kinney Mfg. Co., 3529 Washington St., Boston 30, Mass.*

Mention No. 533 when filling out card.

Stroboscopic Speed Indicator

New "Synchroscope" checks speed of synchronous-speed devices. Cold-cathode triode develops pulses of light at line



frequency, which stroboscopically "stop" motion of synchronous-speed devices.—*Synchroscope Co., 57 William St., New York 5, N. Y.*

Mention No. 534 when filling out card.

Centrifugal Air Cleaner

New line of "Airfuge" separators cleans compressed air by centrifugal force. Separator available in 7 inlet

and outlet tapping sizes, from 0.5 to 2.5 in. Separator removes 99 percent of impurities from compressed air without pressure drop. Impurities are

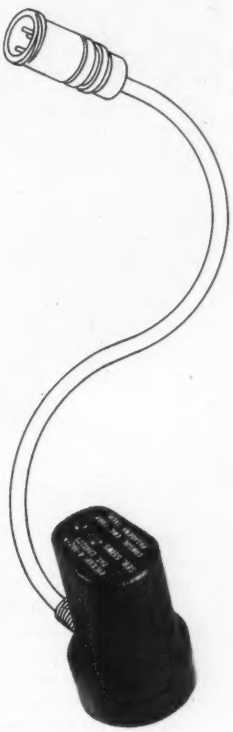
ACCURATE

MEASUREMENT

OF LOW AMPLITUDES

AT LOW FREQUENCIES

Isolation and evaluation of vibration in any of its linear directions becomes a simple matter with the Consolidated 4-102A Velocity Pickup and its high-temperature counterpart, the 4-103. These instruments, highly insensitive to transverse accelerations, allow accurate determination of velocity in *any* linear direction, for their sensitivity does not change with orientation. When fixed to the machine or structure under test, their light weight (12.7 oz.) causes no material change of vibratory characteristics nor spurious damping. Patented spring suspension of the seismic mass completely eliminates friction, thus providing accuracy at extremely low amplitudes and frequencies, where ordinary vibration-measuring equipment often tends to stick.



Consolidated

VELOCITY PICKUPS

For construction detail and operating principle of these CEC Pickups as well as description of indicating or recording equipment used with them, write for Bulletin 1507-X3. TORSIONAL VIBRATION may be measured with Consolidated 9-102 Torsiograph described in the same Bulletin.

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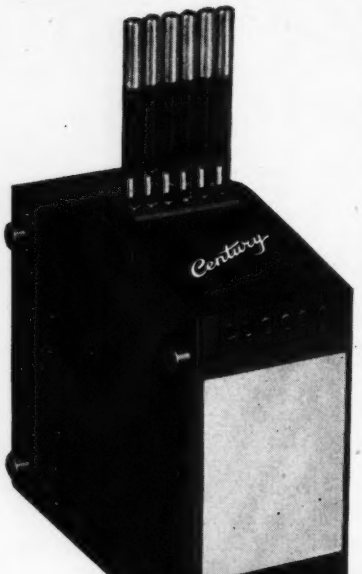
RECORDING GALVANOMETERS



The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

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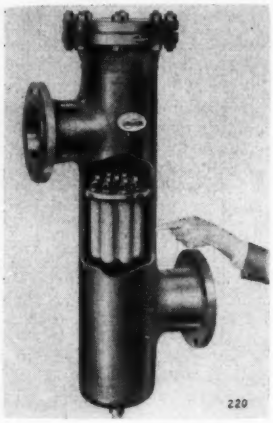
whirled outward to the walls of unit where they drain down to trap section. Float-operated trap automatically releases accumulated liquids as they rise to level above sealing point.—*Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio.*

Mention No. 535 when filling out card.

Air-gas Filters

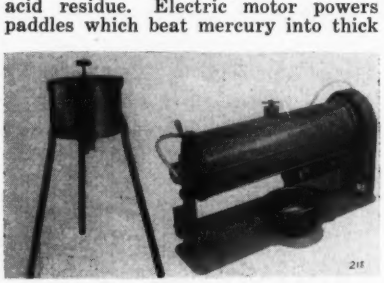
New "Liqui-jectors" deliver clean air or gas to pneumatic systems through liquid-impervious ceramic filters. Liquids and dirt ejected automatically; devices have no moving parts.—*Selas Corp. of America. Erie Ave. & D St., Philadelphia 34, Penn.*



Mention No. 536 when filling out card.

Mercury Cleaner

New large-size mercury oxifier and filter has capacity of 150 lbs.; can clean up to 600 lbs. a day in 150-lb. batches. "Type-H" filter eliminates floating impurities such as water, oil, dust and acid residue. Electric motor powers paddles which beat mercury into thick spray for several hours. Base-metal contaminants coming in contact with air oxidize and form powder, which precipitates as dust and is removed by filter. Residual contamination is less than one part in a million. Oxifier weighs 250 lbs.; has ½-hp. motor operating on 115-v., 60-cycle a-c. source. Filter weighs 40 lbs.—*Bethlehem Apparatus Co., Front & Depot Sts., Hellertown, Penna.*

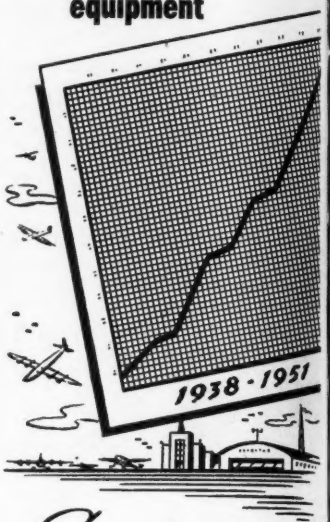


Mention No. 537 when filling out card.

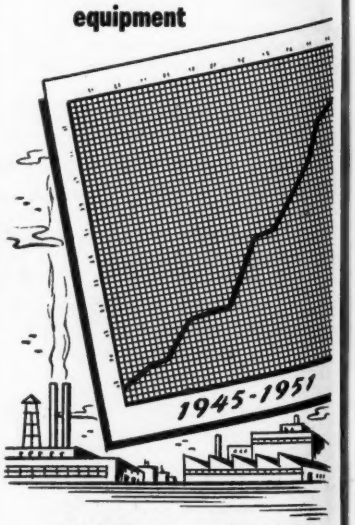
Ground-thread Thermowell

New thermowell has thread of type used on finest gages ground on by machine. Accuracy and surface finish of thread make pressure-tight joint

Specified increasingly on air-borne equipment



Specified increasingly on industrial equipment



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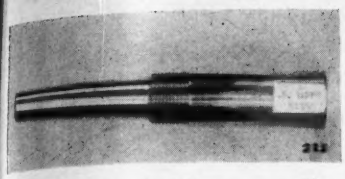
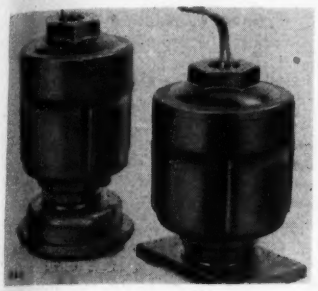


without use of pipe dope or sealing compound.—*Karn Chemical Equipment Co., 518 Dickson Ave., Pittsburgh, Penna.*

Mention No. 538 when filling out card.

Explosion-proof Solenoid Housing

New explosion-proof solenoid housing for maker's electrically-operated pilot-controlled valves is made of cast-alum-

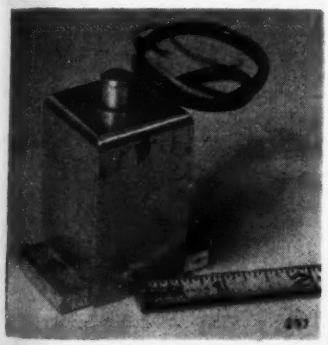


inum to UL specifications, Class I, Group D, Air Break Type. Provision is made for standard conduit connection. *Ross Operating Valve Co., 120 E. Golden Gate, Detroit 3, Mich.*

Mention No. 539 when filling out card.

Sync-signal Pickup

New "Type 140" synchronization pickup consists of 20,000-turn coil wound around magnetized pole piece, which protrudes 0.5 in. through case.



A sync-pulse to CRO trigger sweep is formed when a small piece of steel is moved past pole piece. Output pulse is double-ended and symmetrical, allowing synchronization on positive or negative polarity.—*Sterling Instruments Co., 13331 Linwood Ave., Detroit 6, Mich.*

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Rubberized-fibre Protective Packaging

New use of "Texlite" rubberized curled hair and/or wool is protective packaging of delicate instruments and

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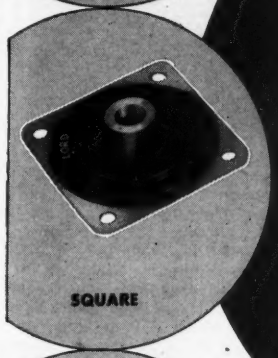
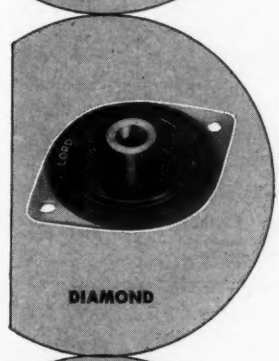
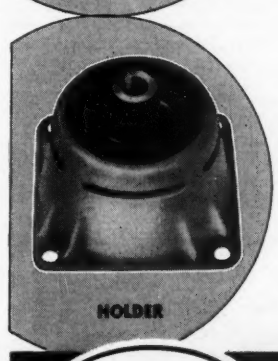
at no increase in price
LORD
MULTIPLANE MOUNTINGS
for All-Direction Vibration Protection







Lord Multiplane Mountings are now protected against attack from oil, gasoline, cleaning solvents, ozone, and other enemies of rubber.

The rubber flexing element is protected by a thin, tough, elastic material which resists attack and prolongs the life of Multiplane Mountings under adverse conditions . . . an added value at no increase in price.

This illustrates LORD policy—to produce the very best Quality BONDED-RUBBER (rubber-bonded-to-metal) parts possible. Through constant research new materials are investigated, new processes tested, and new methods developed to supply long-lasting vibration-control mountings for product improvement.

Vibration control increases accuracy and improves performance of products . . . reduces maintenance . . . builds sales. Investigate Lord Vibration-Control Mountings and Bonded-Rubber Parts. Write to attention of Product and Sales Engineering Department.

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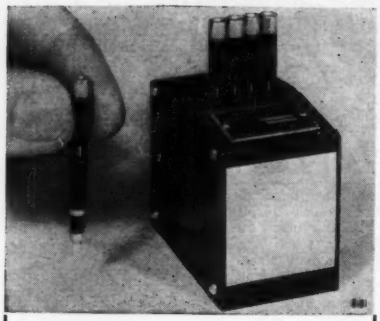


GALVANOMETER MODEL 106-SS

(SUPER-SENSITIVE)

● RECORDS FROM SOURCE WITHOUT AMPLIFICATION . . .

● BALANCE TO LESS THAN .001" PER "G" AT 12" OPTICAL DISTANCE.

A Super-Sensitive galvanometer especially developed by Midwestern for use in recording signals direct from source, without amplification. Because of its precision balance, it is especially valuable in applications where instruments are subjected to extreme vibration—such as in aircraft testing. No special shock mounting is normally required.

The regular production model balance of .003" per "G" is much better than any production models previously offered. For special applications of severe vibration conditions this galvanometer can be balanced to less than .001" deflection per "G". Also, the "bow-string" effect, present in some degree in most galvanometers, has been practically eliminated due to a new suspension design.

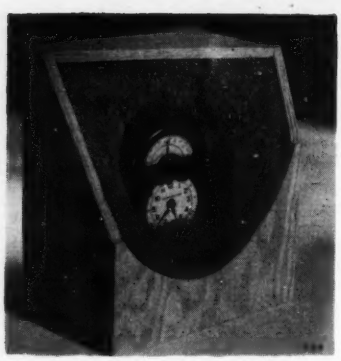
This galvanometer has individual circuits for both terminals of the elements. Element tube O.D. is .187", and length is 2.062". It is used in Midwestern's magnet structure M-153. Center distance between elements, is .195". Characteristics of elements are shown below.

SS Type	Nominal Undamped Natural Frequency	D.C. Sensitivity 12" Optical Arm (Undamped) Ma/In.	Nominal Galvanometer Resistance Ohms
106-100	100	0.005	35
106-150	150	0.012	35
106-200	200	0.020	35

Write for Bulletin Osc. 12-50-C

MIDWESTERN
GEOPHYSICAL LABORATORY

2803 W. 40th • Tulsa, Oklahoma

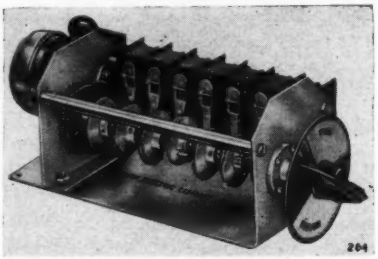


costly equipment. Made of interlaced fibres of either hair or wool, rubberized and vulcanized into compact non-shredding material. Density range is from 1.5 to 5 lbs. per cu. ft. Packing is moisture resistant and vermin and fungus proof. Available in 51 x 60-in. sheets and thicknesses of 0.75, 1, 1.5 and 2 in. or multiples thereof. Die-cut shapes also offered.—*Sponge Rubber Products Co., 471A Derby Pl., Shelton, Conn.*

Mention No. 541 when filling out card.

Multiple-circuit Timer

New multiple-circuit timer has a bank of s-p.d-t. micro-switches operated by adjustable cams driven by a



synchronous motor. Unit is available without motor, and for one-cycle operation.—*Zenith Electric Co., 152 W. Walton St., Chicago 11, Ill.*

Mention No. 542 when filling out card.

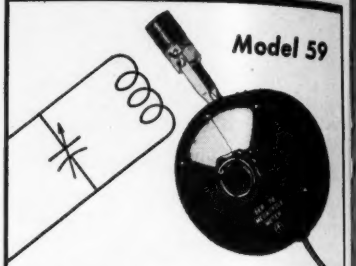
Hermetically-sealed Electronic Timer

New electronic timer is hermetically sealed in a sheet metal can 2.31 × 2.06 × 3.13 in. Time intervals from 0.1 to 10 sec. are factory preset. S-p.d-t. relay is rated 1 amp. non-inductive load. Unit operates from 105 to 125-v. 360 to 1200-cps. power supply. Time cycle is started by a contact closure; an RC circuit discharges through a gas-filled tube to operate relay.—*C. G. Wilson & Co., 2 N. Passaic Ave., Chatham, N. J.*

Mention No. 543 when filling out card.

Time-delay Relay

New "Type TEC & TER" time-delay relay has differential-gear clutch motor, consisting of an internal-tooth planetary-gear system. When locked by braking relay internal gear causes motor to drive output shaft. When braking relay is released, mechanism is instant-



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Frequency Accuracy ±2%

The MULTI-PURPOSE INSTRUMENT

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110-120 volts, 50-60 cycles; 20 watts.

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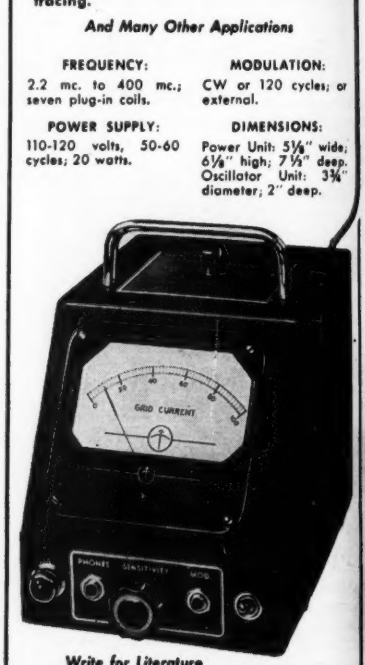
Power Unit: 5⅛" wide; 6⅛" high; 7½" deep. Oscillator Unit: 3¾" diameter; 2" deep.



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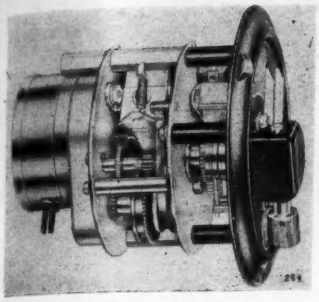
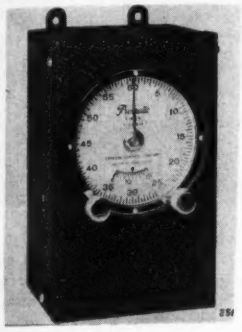


ly reset to start position by reset spring. Relays provide adjustable or fixed time-delay between operation of a control circuit, and subsequent closing or opening of a load circuit.—*The R. W. Cramer Co., Inc., Centerbrook, Conn.*

Mention No. 544 when filling out card.

Synchronous-motor Timer

New "Type SY Promatic" synchronous-motor timer controls time periods between 0.5 sec. and 24 hrs.; actuates five s-p.d-t. load contacts independent

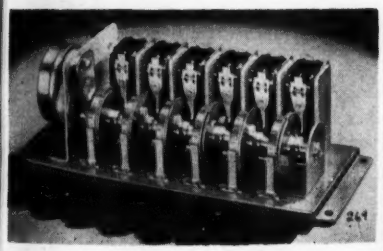


of the timer-control circuits. Has two solenoids, one for clutch and timing mechanism, one for load contacts. Resets automatically for each cycle. Preset interval and elapsed time are both visible on 3.38-in. dial. Available for 115 or 230 v. a.c.—*General Control Co., Boston 34, Mass.*

Mention No. 545 when filling out card.

Multi-cam Timer

New multi-cam recycling timer has a group of cams, which operate snap-action switches, mounted on a single shaft driven by a synchronous motor.



Percentage calibrations on each cam face permit individual adustment for ON and OFF periods ranging from 2 to 98 percent of time cycle. Nine models are available, with time cycles from 1 rev. in 40 sec. to 1 rev. in 72 hrs.—*Industrial Timer Corp., Newark, N. J.*

Mention No. 546 when filling out card.

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Hair-operated and calibrated to professional standards of accuracy by the maker of the world's finest weather instruments. Handsome, modern case—4" high, 5½" wide, 1⅝" deep.

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Accurate readings obtainable without special skill. Psychrometric readings can be taken at any point desired however inaccessible.

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Portable Humidity and Temperature Recorder
3" x 5" charts, 10 or 30 hour records. Modern design...handy for small space and difficult locations ... built to meet unusual conditions.

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The foremost relative humidity recorder for laboratory, factory, and office use. Scientifically designed for accuracy and dependability.

Model 573
Motor Aspirated Psychrometer
Designed to determine wet and dry bulb temperature with laboratory accuracy—Motors supplied for use on 115 V., 50 cycles or 60 cycles.

Model S/1
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A small, low cost instrument. Thermometers graduated in 1° increments from +35° F to +110° F. Furnished complete with case and psychometric slide rule.

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In several fields of fractional H.P. motor use, OSTER is the world's largest producer—electric barber clippers and massage instruments, for example. OSTER electric housewares, including food mixers, knife sharpeners, and hair dryers, because of their outstanding design and efficiency, are currently national best sellers.

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Interval Timer

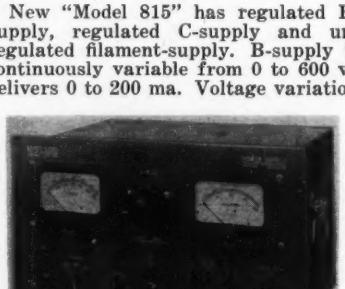
New interval timer has ranges from 1 to 60 min. available. Setting knob is directly connected to switch-operating cam. Motor operates on 115 v.

50 to 60 cps.; switch is rated 1000 watts non-inductive load. Unit is available for surface or panel mounting.—*Zenith Electric Co., 152 W. Walton St., Chicago 10, Ill.*

Mention No. 547 when filling out card.

Voltage-regulated Power Supply

New "Model 815" has regulated B-supply, regulated C-supply and unregulated filament-supply. B-supply is continuously variable from 0 to 600 v., delivers 0 to 200 ma. Voltage variation

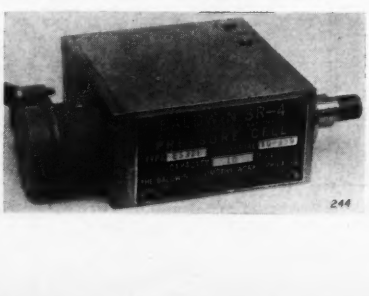


is less than 0.5 percent for line fluctuations from 105 to 125 v. and for load variations from 0 to 200 ma. Ripple is less than 5 mv. C-supply is variable from 0 to 150 v., delivers 5 ma. A-c. output is 6.3 v. 10 amp., center-tapped.—*Kepco Laboratories, Inc., 149-14 41st Ave., Flushing, N. Y.*

Mention No. 548 when filling out card.

Pressure Cells

New "Type-E" pressure cells are insensitive to linear acceleration and position. Capacities are 10, 20, 50, and 100 lb. per sq. in. Operation is based on SR-4 strain gage with four-arm Wheatstone bridge. Measuring range from absolute vacuum to full-rated pressure, except in 10-lb. unit for which range is plus or minus 10 lb. per sq.



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in. Cells are designed for standard 120-ohm circuit. Recommended input is 5 v. Cells are temperature compensated. Calibration accuracy is within 0.25 percent of full scale.—*Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.*

Mention No. 549 when filling out card.

High-power Triode

New air-cooled transmitting and power triode has plate dissipation of 45 kw. and weighs 66 lbs. Tube uses radiator fins and air-flow chamber. Pro-

duces output of 108 kw. at 15 mc. and operates to 30 mc. Max. plate voltage is 13,500 v.; max. plate current is 12 amp.—*Amperex Electronic Corp., 25 Washington St., Brooklyn 1, N. Y.*

Mention No. 550 when filling out card.

High-temperature Soft Solder

New "No. 50" alloy solder is composed of lead, tin, and indium. Melting point is 600 F. and a high degree of wettability is claimed. Holding strength is 3500 psi. and tensile strength 5200 psi. Both acid and rosin fluxes can be used; solder is available in wire, bar, and ribbon form.—*Soldering Specialties, Summit, N. J.*

Mention No. 551 when filling out card.

Honey Refractometer

New refractometer determines moisture content of honey; requires only few drops of honey sample for examination. Scale covers range from 12.5 to 27 percent moisture and thermometer, graduated in percent of moisture, is attached to instrument for temperature correction.—*Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.*

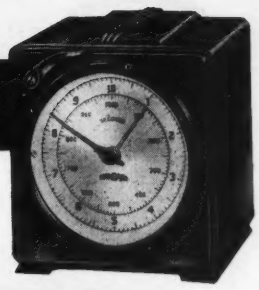
Mention No. 552 when filling out card.

Tensional Load Cells

New "Type P" load cells for measuring forces in tension only have load capacities of 10,000, 20,000, 50,000 and 100,000 lb. Other sizes made to order. Cells use SR-4 strain gages bonded to load-carrying shaft. Accuracy of measurement is 0.25 percent of rated capacity. Cells are temperature and modulus compensated and relatively impervious to moisture and dirt by O-ring seals.—*Baldwin-Lima-Hamilton Corp., Philadelphia 42, Penna.*

Mention No. 553 when filling out card.

Standard TIMERS



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Model	Scale Divisions	Totalizes	Accuracy
S-100	1 5 sec.	6000 sec.	±.1 sec.
S-60	1 5 sec.	60 min.	±.1 sec.
SM-60	1 100 min.	60 min.	±.002 min.
S-10	1 10 sec.	1000 sec.	±.02 sec.
S-6	1 1000 min.	10 min.	±.0002 min.
S-1	1 100 sec.	60 sec.	±.01 sec.
MST	1 1000 sec.	360 sec.	±.001 sec.
MST-500	1 1000 sec.	30 sec.	±.002 sec.

Write for Timer Bulletin 153

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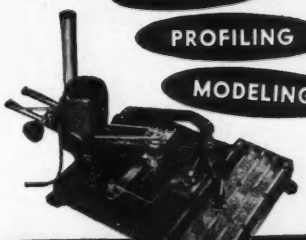

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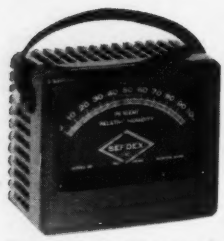

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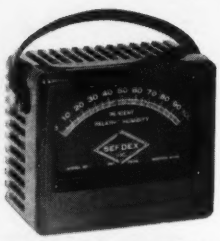

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SIZE — 4½ x 4 x 3" — weight — 11 ounces.

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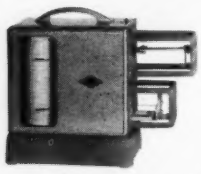
STANDARD MODEL — This *new* model was brought out January 1, 1951 and is identical in all respects to the Laboratory Model — except the degree of accuracy, which is warranted as ±3% R.H. Ideal for general use where higher order of accuracy is not required. **Price $30.00** delivered — U.S.A.



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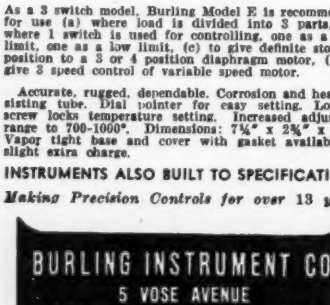

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only 1 light-weight moving part. Available with 1, 2 or 3 switches.

As a 3 switch model, Burling Model E is recommended for use (a) where load is divided into 3 parts, (b) where 1 switch is used for controlling, one as a high limit, one as a low limit, (c) to give definite stops or position to a 3 or 4 position diaphragm motor, (d) to give 3 speed control of variable speed motor.

Accurate, rugged, dependable. Corrosion and heat resisting tube. Dial pointer for easy setting. Locking screw locks temperature setting. Increased adjustable range to 700-1000°. Dimensions: 7¼" x 2¾" x 3½". Vapor tight base and cover with gasket available at slight extra charge.

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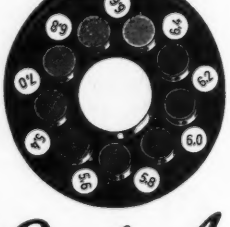

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[COVER FEATURE]

This new unique control and indicating board was designed by Dow engineer, J. H. Meserve, and is installed in the new South Power Station, Midland, Mich. The upright board contains the recording and indicating instruments for two cyclone boilers and the console board in the foreground contains the controls for the combustion control system and the upright of the console contains the auxiliaries for the two boilers. On the back of this board is incorporated the indicating board for the turbine also the control and indicating board for three reducing stations. The turbine board in the picture is a double extraction automatic back pressure turbine 1250 psi. 900 F. to 25 psi. Extraction pressures are 425 psi. and 165 psi. Control board was fabricated by Falstrom Company, Passaic, New Jersey.

SORTING MIXED METALS

Continued from page 527

energy escapes in the form of photons of radiant energy.

Roughly speaking, the difference value between the attained energy and the original energy, which is a function of the nature of the atom as well as the degree of excitation, determines the radiant frequency of the photons reaching the entrance slit of a spectrograph. The radiant energy received by the spectrograph must in turn be dispersed and discriminated by an optical element such as a prism, interferometer plates or a diffraction grating and then measured as to magnitude as well as frequency—both conditions being indicative of the kind and amount of alloying elements present in the parent sample. Thus, each element carries with itself its own unmistakable fingerprint (Fig. 13).

A detailed discussion of the technology of spectrum analysis work would be far beyond the scope of this paper and redundant in the face of many texts and hundreds of excellent papers covering every industrial phase of the subject. However, we make the bald statement, herewith, that some form of spectrochemical equipment will be found to be the ultimate answer to all of the analysis problems of the metals industry—including those dealing with the determination of metalloids, compounds, gases and other currently obstinate spectrographic problems.

During the past fifteen years the large spectrograph has stepped down from its lofty perch in the research laboratory onto the melting house floor. In this it has been assisted not only by scientists, engineers and technicians, but mainly by far-sighted, economics minded businessmen; for the price of development in industrial spectrum analysis equipment comes high. Let us hope that our "white-haired boy" will be assisted eventually into the middle of that rusty pile of mixed billets out behind the gas house. That day is

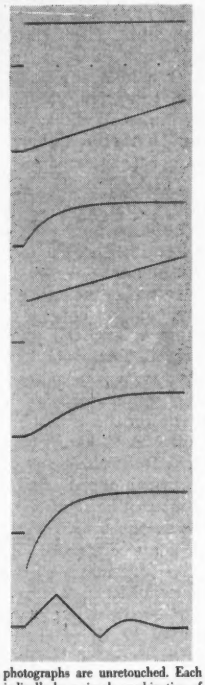
Some Primary DYNAMIC RESPONSES

The transients initiated by specific stimuli, like a common language, serve to relate and identify dynamic structures among technologies which are otherwise diverse.

Under transformation of the variables, how many different basic systems are represented by the responses below?

In this case the ordinate scale is ten volts; the unit for the concurrent time abscissae is 0.0004 seconds.

UPPER FIGURE IS STEP-FUNCTION USED AS STIMULUS. BELOW ARE TABULATED OPERATORS TOGETHER WITH RESPONSES THEY PRODUCE.



$\frac{1}{5p}$

$\frac{1}{1+p}$

$\frac{1+5p}{5p}$

$\left(\frac{1}{1+p}\right)^2$

$\frac{1-p}{1+p}$

$\frac{3p}{1+3p+9p^2}$

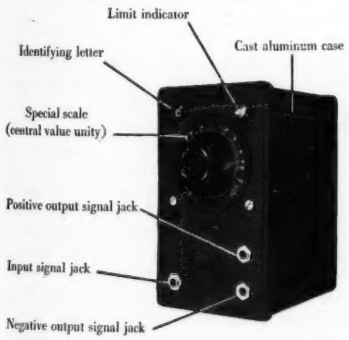
BOUNDED FIRST DERIVATIVE

The above oscilloscope photographs are unretouched. Each response was computed periodically by a simple combination of GAP/R Electronic Analog Computor Components. Phenomena of any complexity, non-linear as well as linear, may be embodied and represented in this manner. Quantitative studies are speedily pursued through the use of this ultra-modern tool of synthesis.

Typical GAP/R Computor Component

Employed for the direct adjustment of local sensitivity in analog assemblies. Outputs are plus and minus the input signal multiplied by the numerical dial setting (0-100).

Model K3-C Coefficient Component



This component is one of a dozen similar types which are available from stock. Each performs a specific dynamic or mathematical operation, and is specially engineered to play its part most efficiently in any computing assemblage. Convenient to use, economical to buy, and of wide applicability, our GAP/R Analog Computor Components are now assisting study and development programs in many different fields. Is it not probable they can help you too?

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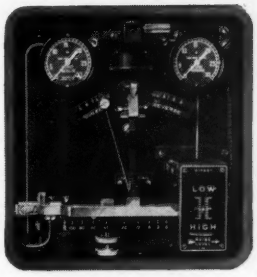
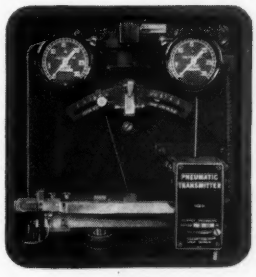
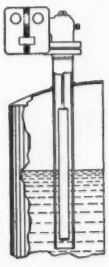


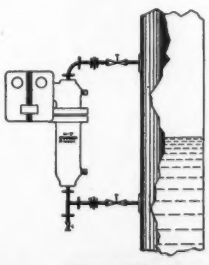
Model 12600
Proportional Control



Model 12620
Pneumatic Transmitter



Top Vessel Mounting



Top and Bottom
Screwed Connections

Nowhere except in the Masoneilan 12,000 Series Variable Displacement Level Controllers will you find such a wide choice of essential characteristics.

Wide Variety of Controller Types

Proportional controller, proportional plus reset controller, pneumatic transmitter, two-position differential gap controller, three-position pneumatic signal switch; duplex types — proportional controller and pneumatic transmitter, proportional-reset controller and pneumatic transmitter, proportional controller and pneumatic signal switch (and other combinations as required).

Selection of Mountings

Two internal mountings—top or side vessel flanged connection; eight external mountings — displacer chamber with screwed or flanged connections arranged for best adaptability to a variety of vessels. Right or left hand instrument case mounting.

Selection of Torque Tube Materials

Selection of torque tube assembly material best suited for the application. Standard is Inconel. Monel, Type 316 Stainless Steel, or Phosphor Bronze also available. (Materials offered subject to availability during shortages.)

Available in Many Ranges

12,000 Series Level Controllers are available in many standard ranges — 14 and 32 in.; 4, 5, 6, 7, 8, 10 and 15 ft. Other ranges can be supplied for special applications.

Meet Great Variety of Applications

Typical applications include level in fractionating or crude towers, accumulators, separators, sumps, chillers, feed water heaters, settling tanks — many other applications.

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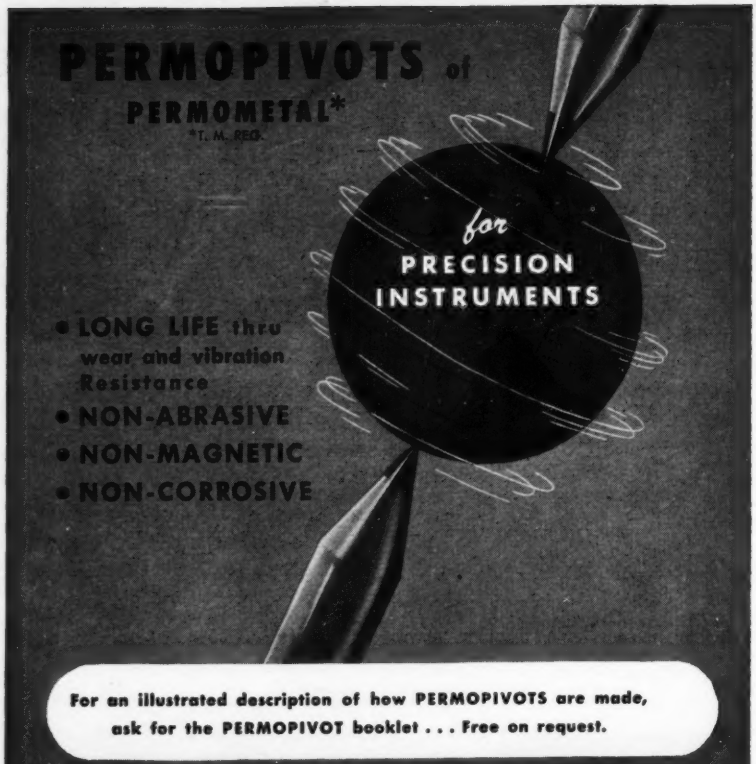

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not far away: as a matter of fact, it is here already in some respects.

The Ford Motor Company has pioneered not only in the industrial application of the large spectrograph for routine "heat" analyses but also in the design and operation of their remarkable motorized laboratory. A paper describing this laboratory was presented in 1948 by its designers, Henry A. Tuttle of the Chemical & Metallurgical Research Department and George A. Nahstoll of the Chemical Engineering Department, and should be treated as a catechism by the metals industry.

Tuttle and Nahstoll drive the Motorized Laboratory around to locations of mixups in a Ford panel delivery truck —hauling no less that the following equipment: A work bench, a set of selected chemical spot test kits, apparatus for color carbon, a high-speed grinder and hood for spark testing, Brinell, Rockwell and Scleroscope hardness testers, a magnetic plating-thickness gage and a semi-portable spectroscope of the precalibrated, small-prism type. A 3-kw. generator mounted in the cab of the truck furnishes the spectrograph source power. All other equipment can be powered either by plugging inside the truck or by reeled extensions at some distance from the truck.

At present, the semi-portable spectrographic instruments are all of the type which depend upon the visual acuity of the operator. That is, spectrum lines of the sought-for elements are selected, recognized and compared with known standard lines, principally those of the iron spectrum in steel work. This is done in a visual field. The next step, it would seem, should be toward the development of relatively small, portable "direct readers" which employ phototubes and panel instruments to indicate or record the analysis of a sample.

But the instrument itself is not the only problem; the sample excitation source, which is currently a d-c. arc or a high-voltage spark, is not only complicated and not too reproducible except under carefully controlled conditions but can be fatally dangerous to operating personnel. The development of these problems into a well integrated and easily managed instrument will be just as costly, in spite of the background of good work from which we can draw, as that of any other major step in spectrographic equipment. Fortunately, however, associated fields of technology have uncovered several fundamentally sound possibilities to employ in our aim to reach the ultimate goal of a "direct reader" spectrograph in a suitcase.

So now we can make mystic passes with impunity and our magic wands wax hot in many plant; our magicians are erudite and industrious and, in at least a few cases, have stages which are all their own. But we call for more magic—impromptu magic—for which the props are not yet built.

There are times when the only words to describe the situation are those of Mortimer Snerd: "Well—that's the way it goes!"

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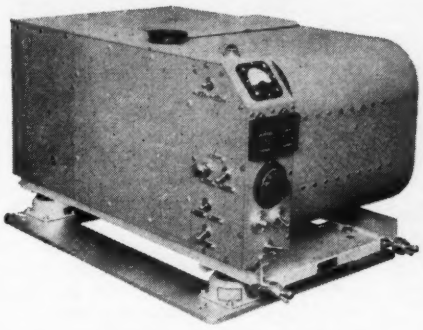
RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

Size: 20" long, 12½" wide, 8⅞" high.

Weight: 60 pounds.

Number of Recording Channels: 6 to 50.

Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.

Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.

Paper speeds continuously and instantly variable without changing gears or sprockets.

Separate optical system for viewing before or during recording.

Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.

Data numbering at beginning of record.

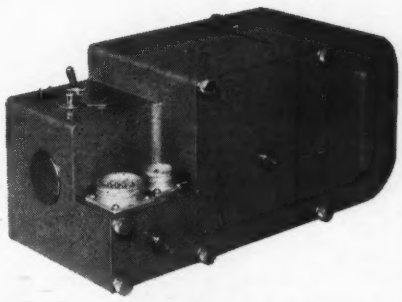
Footage indicator showing amount of paper remaining in magazine.

Automatic record length control.

Trace identification.

Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

Size: 5" x 5" x 11".

Weight: 11 pounds.

Cast Aluminum case.

Paper speeds variable ½" to 12" per second.

Detachable daylight loading magazine with a capacity of 3⅜" x 50' paper or film.

2 to 12 individual channels.

Trace identification.

Trace viewing.

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INSTRUMENTS ON THE MARCH

Wide-range R-f. Micropotentiometer

WASHINGTON, D. C.—Extremely simple devices which produce r-f. voltages at a very low impedance and at a wide range of frequencies have been conceived and developed by M. C. Selby of the National Bureau of Standards. Known as "r-f. micropotentiometers," they provide accurate voltages from 1 to 10^5 microvolts without the use of attenuators at frequencies above 300 mc. Thus, convenient standards of low voltages are made available which should greatly reduce equipment and shielding problems encountered in calibration of present-day commercial voltage generators, attenuators, voltmeters, and other r-f. equipment.

The micropotentiometers should prove especially useful in measurements of radio-receiver sensitivity. The large disagreement between various voltage-generators at high frequencies and low voltage levels has been due to three major causes. First, generator output-impedance and receiver input-impedance are not ordinarily known as functions of changing frequencies. Second, extreme care is necessary in using precision voltage-dropping attenuators. Finally, the long-time calibration stability of vacuum-tube voltmeters is uncertain. For these reasons, manufacturers of voltage generators have not been able to guarantee the accuracy of their equipment at all frequencies. Development of the micropotentiometers now appears to have removed most of the obstacles to standardization of receiver sensitivity.

The new instruments consist essentially of current-carrying elements with means for monitoring the currents they carry. Electrical constants are determined from the known direct-current

Torquemeter on Aircraft Test Stand

PHILADELPHIA, Pa.—Measuring torque without taking power from the drive shaft, Royal Dutch Airlines takes this and other test measurements to correct performance of the superchargers that pressurize its airplane cabins when flying at high altitudes.

The supercharger (left) is driven through a gear box (center) and a variable-speed hydraulic transmission by a 150-hp. electric motor. Between gear box and transmission is a Baldwin Torquemeter incorporating SR-4 resistance-wire strain gages. Torque is recorded in inch-pounds on a panel-mounted instrument.

This method of measuring torque was made possible by bonding special SR-4 strain gages to a short length of shaft so as to form an electrical Wheatstone bridge. The corners of the bridge are connected through slip rings on the shaft to stationary brushes in the case which is kept from rotating by a bracket bolted to base of gear case.

Royal Dutch Airlines has installed what is believed to be the first completely automatic, universal test stand at the Schiphol airport near Amsterdam, Holland. The installation was made to overcome the limitations arising from operating several thousand miles from the American factories that manufacture the airplanes used.

Torquemeter on aircraft test stand.

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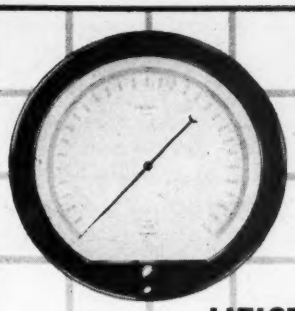

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There are no stock gauges. Every Heise Gauge is manufactured on special order. Ranges: 0-15 to 0-10,000 psi. Sizes: 8½", 12" and 16". Prices: $151.60 to $211.20. Gauges for use with mercury are $20.00 extra. Write for catalog.

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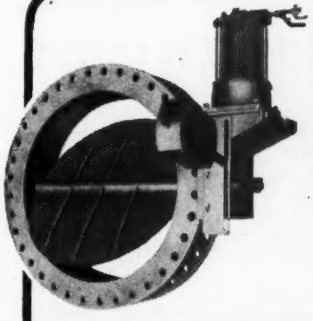
Newtown, Connecticut



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30" butterfly valve for 60 p.s.i. pressure, with Limitorque motor control and auxiliary handwheel, position indicating lights and push button.

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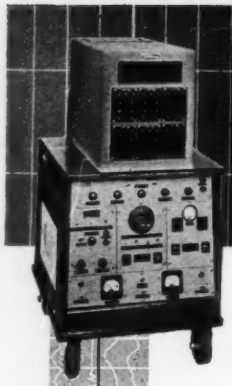

NEW HIGHS IN RESOLUTION

The Hathaway SC-16A Six Element Recording Cathode-Ray Oscillograph, designed for recording fast transients and continuous phenomena, brings you new highs in resolution because of its unusually high frequency response and high chart speed. Note these unusual features:

FREQUENCY RESPONSE 0 to 200,000 cycles per second • RECORDS up to 1000 ft. long at speeds up to 600 inches per second • RECORDS up to 10 ft. long at speeds up to 6000 inches per second • WRITING SPEED as high as 5,000,000 inches per second • SIX ELEMENTS with interchangeable lens stages for 1, 2, 3, or 6 traces on full width of chart • INTERCHANGEABLE RECORD MAGAZINES for continuous recording or short record of fast transients • PRECISION TIMING tuning fork controlled QUICK-CHANGE TRANSMISSION for 16 record speeds • AUTOMATIC INTENSITY CONTROL • CONTINUOUS SWEEP OSCILLATOR.

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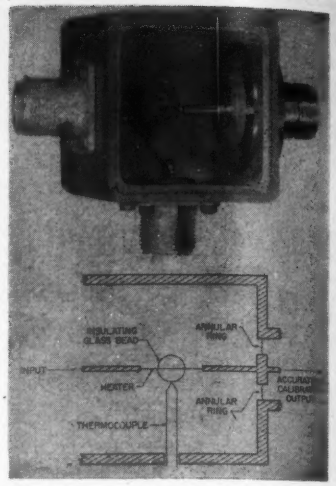


Exposed view and functional diagram of r-f. micropotentiometer.

voltages and currents. The current-carrying elements are annular membranes, either metallic or nonmetallic, of various radii, thicknesses, and electrical resistivities. Monitoring may be accomplished by means of thermocouples, thermoelements, bolometers, stable vacuum-tube voltmeters, or other devices whose indications are independent of frequency.

These micropotentiometers are the first low-impedance (of the order of milliohms) devices which provide r-f. voltages in the microvolt range and which make these low voltages available without the use of attenuators. They thus provide useful tools for many problems where constant voltage and low voltage sources are required. The devices are inherently frequency insensitive up to and above 300 mc. Extremely low and essentially nonreactive output-impedance facilitates their use for checks and references with standard voltage generators. Simplicity of operation, trouble-free circuitry, flexibility, and absence of serious shielding problems make these instruments particularly adaptable to use by personnel of limited training.

In comparing the micropotentiometers with other sources, such as a

Micropotentiometer setup for calibrating a millivoltmeter.

voltage-measuring thermistor bridge*, absolute reproducibility and agreement have been limited only by the relative complexity of the standards of comparison. Verification of the exact frequency and voltage ranges of the micropotentiometers in terms of other independent standards is still in progress at the Bureau, along with other phases of design and application. Probably the greatest single difficulty encountered in this work has been the lack of stable sensitive receivers which can indicate one microvolt (or lower voltages) at 100 mc. and higher frequencies with accuracies of 10 percent or better. However, available evidence appears sufficient to recognize in "r-f. micropotentiometers" reliable, economical, and critically needed instruments for standardization of both single-ended and balanced-voltage circuitry.

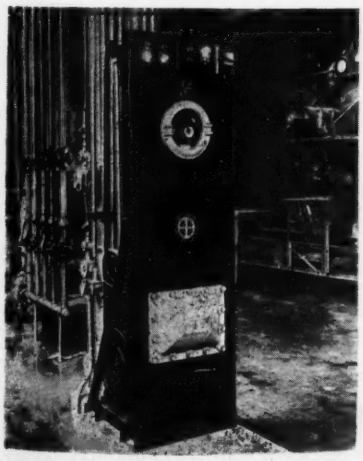
The illustrations show an exposed view, a functional diagram, and a setup for calibrating a millivoltmeter. Annular-ring membranes of different resistivities are interchangeable for desired millivolt ranges. In use, an r-f. power source supplies the unit. A filter box on top the unit eliminates radiation from the leads to the thermocouple d-c. output monitor.

*A bolometer bridge for standardizing r-f. voltmeters, M. C. Selby and Lewis F. Behrent, J. Research NBS 44, No. 1, 15-30 (1950).

Safety Instrumentation

EAST ST LOUIS, Ill.—Recognizing the high hazards of combustible solvent extraction, management of the Hunter Packing Company at East St. Louis, Illinois, specified extreme precautionary measures for the company's rendering plant constructed a little more than a year ago. Strictly observed safety regulations and continuous, scheduled use of scientific equipment and instruments have since paid dividends to the company in its safety record.

One of the first safeguards deemed necessary was a reliable alarm system to warn of concentrations of vapors approaching combustible limits. The



Combustible gas alarm analyzes continuously eight air samples.

Enjoyment of twenty-one hours of continuous record music from one loading is now possible with the Lincoln Record Changer. Plays both sides of your records...all sizes ...all speeds...on a cushion of air. This new design uses air as the motive power for transferring each record to the turntable and for turning it over. A reliable Bodine motor is used to drive the vacuum pump.

Outstanding reasons for their selection of Bodine motors were given by the Lincoln Engineering Company: "exceptionally quiet and smooth running, ability to meet power and size requirements, Bodine's excellent reputation for high-quality motors, outstanding co-operation received in helping us select the proper motor for our needs...all the above advantages at a competitive price."

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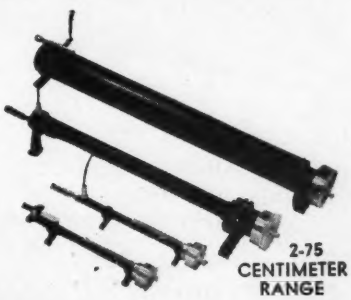

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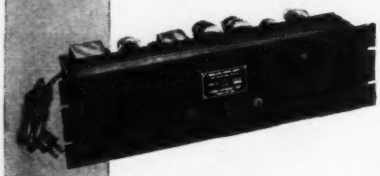

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- **OUTPUT #1:** 200 to 325 Volts DC at 100 ma regulated
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- **RIPPLE OUTPUT:** Less than 10 millivolts rms

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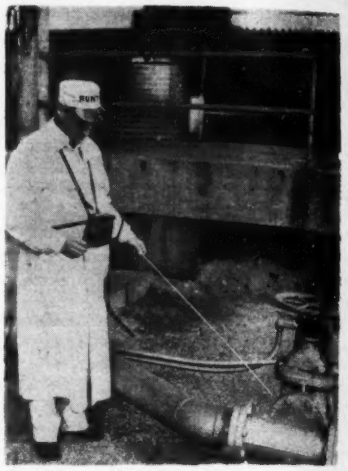
Air samples are drawn from eight different locations to the instrument which is in a prominent spot and easy to see. A turbo-compressor vacuum pump in the unit aspirates for the air samples. In the instrument is a motor-



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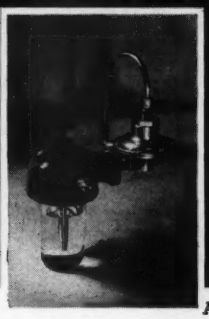

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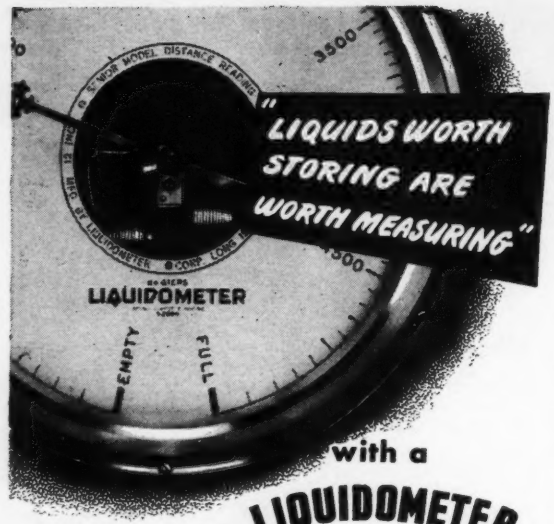

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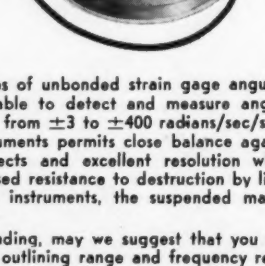

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PHOTOELECTRIC MEASUREMENT OF DUST

Continued from page 544

the position of the measurement, and the particle size distribution of the material being sampled affect the indication.

First, consider the sampling of a very fine material. Because of their small size, the particles remain suspended in the air for a long period of time. The particle size distribution is independent of air velocity. Therefore, in the sampling procedure, no consideration need be given to the

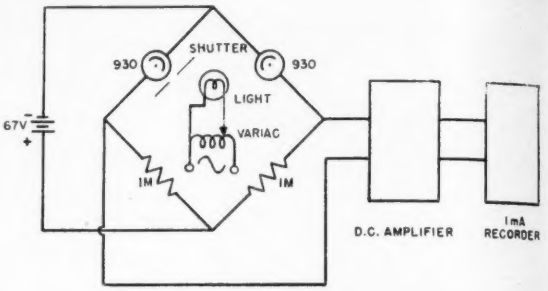

Fig. 4. Schematic of bridge-type smokemeter.

losses caused by settling in the pipe or by centrifugal separation at the 90-degree bend in the pipe. As a result, if the sampling velocity is greater than the duct velocity, the smoke density is diluted; if lower than the duct velocity, the density is concentrated. Fig. 5 shows a sampling curve which illustrates this fact. Although Zimmerman[5] and Fahrenbach[6] did not obtain their curves under the conditions discussed, their results are applicable.

However, consider a material in which the particle size distribution in the air stream is a function of the air-stream velocity, as is true in many precipitator applications. The

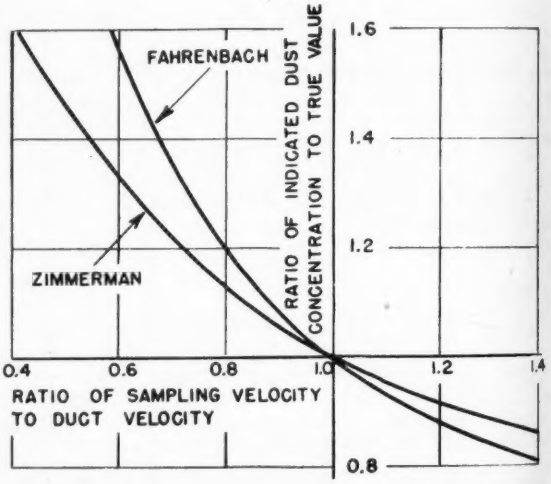

Fig. 5. Sampling characteristics according to Fahrenbach and Zimmerman.

supporting force tending to hold particles in an air stream is a function of the viscosity, density, velocity, and turbulence of the air. These conditions can be indicated by means of Reynolds number. At low Reynolds number, the supporting forces are small and only small particles can be supported. As the velocity is increased, the Reynolds number increases and larger particles can be supported. Therefore, in sampling such a material we need to consider, not the velocities existing in the main duct and sampling tubes, but the respective Reynolds number.

Another important consideration is the centrifugal separation of such a material at the 90-degree bend in the tube. The curves shown in Fig. 6 illustrate the effect of settling

and separation. When the sampling velocity is less than or equal to the duct velocity, the loading indication is low due to the settling in the sampling tube. The ratio of the Reynolds numbers is 6:1. As the sampling velocity is increased, the loading indication increases until, at a velocity ratio of approximately 3 to 1, the indication reaches a maximum. The Reynolds numbers are not equal at this point, but dilution of the sample is now important, as in centrifugal separation. Beyond this point, the dilution of the sample is predominant and the loading indication steadily decreases.

The following conclusions can be drawn from this study:

1. A true loading indication cannot be obtained by a sampling velocity equal to the duct velocity.

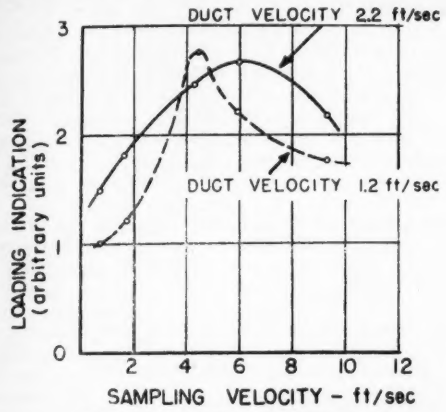

Fig. 6. Characteristics of sampling.

2. An optimum indication is obtained at a higher sampling velocity—the value depending on the particle size of the dust.

3. No true indication can be obtained by these means.

Theory

Photoelectric measurements can be accomplished by measuring either the absorption of light by the dust-laden air, or the scattering produced by the dust. In either case, the measurement depends on the wavelength of the light, the particle-size distribution of the material, and the surface properties of the particles.

Theoretical expressions for the light absorption in dust-laden gases cannot be derived except for the simplest conditions, and parameters obtained by experiments have to be employed in practice. Simon and Kron[4] derived a theoretical expression for the light absorption by dust of single particle size; in this case, the intensity of the light at a distance "l" from the entrance of the light into the dust-laden air is given by

$$I = I_o \, e^{\frac{-3ml}{4r\rho}}$$

where I_o = light intensity at the entrance into the dust-laden air
m = loading in weight/unit volume
l = length of absorption path
ρ = density of the material of the particles

When this expression is extended to include a certain distribution of particle size, it becomes

$$I = I_o \, e^{-me/D(n)\frac{3}{4r\rho}\,dn}$$

where $D(n)$ represents the distribution function of the particles. This can be reduced to the form:

$$I = I_o \, e^{-am}$$

where a is a lumped "constant" for a given set of conditions.

The dust loading, m, can be expressed in terms of the measured light intensities because $m = (1/a) \ln (I_o/I)$. Therefore, a knowledge of a would enable a calculation of

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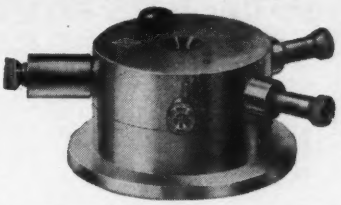

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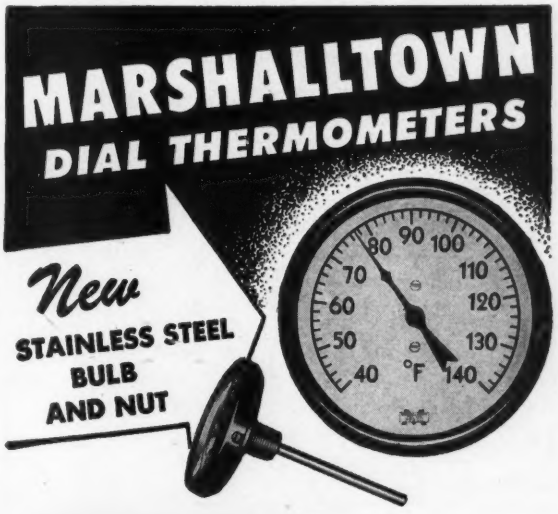

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the dust loading. However, a theoretical determination of this lumped "constant" is very difficult, and in most cases impossible because the distribution function is unknown. Thus it appears that the absorption-type photoelectric smokemeter is a qualitative instrument, unless the constant a can be determined by other means. However, the instrument can be used as a comparison-type instrument, that is, the ratio of loadings can be obtained from the ratio of the values of (am). The ratio of the loadings is expressed by

$$\frac{m_1}{m_2} = \frac{(a_1 m_1)}{(a_2 m_2)} = \frac{\ln(I_o/I_1)}{\ln(I_o/I_2)},$$

if we assume $a_1 = a_2$.

This application is very valuable in determination of precipitator efficiency because $m_1/m_2 \times 100$ can be the percent residual when m_2 is the output loading with the precipitator off, and m_1 the loading with the precipitator on. The assumption that $a_1 = a_2$ is tenuous in precipitator application because the particle size distribution in the output is different from that in the input. This difference is caused by the selective nature of the precipitation process. However, experience has shown that the assumption yields results within a reasonable accuracy for laboratory experimentation.

In our laboratory work it has been possible to find the constant a for the conditions involved and thus to use the photoelectric smokemeter as a quantitative instrument. The equipment used in this calibration is shown in Fig. 1. At a fixed air velocity, gypsum-laden air was drawn through the duct, and the dust was collected by the experimental electrostatic precipitator, which was operating near 100 percent efficiency. The loading of the air stream in arbitrary units was determined from the readings on the smokemeter ($am = \ln I_o/I$), and the actual loading was found from the weight of the material collected and the volume of air drawn through the precipitator. The value of a was computed from these two results, and its variation with particle size was determined by similar experiments with the same material of different average particle size. It should be noted that the values for the lumped "constant" obtained in the way described are valid only for this particular system, dust, and wavelength of light.

One interesting result of the particle-size measurements was the variation of a with average particle radius. It was found that increasing the average particle size from 5 to 18 microns in radius decreased the value of a by a factor of 2. This suggests that a varies approximately inversely as the square root of the radius, for the material and particle distribution involved. It is not suggested that this is a general relation; it is offered only to show that the Simon and Kron equation is probably of the proper form.

Acknowledgement.—The authors wish to express thanks to Dr. Eric A. Walker for his guidance during the work, and to the Koppers Company for sponsoring the research program.

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(2) C. E. Brown, Bureau of Mines #R. I. 3788, 1944.
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(5) E. Zimmerman, *Zeitschr d. Ver. Deut. Ing.*, 75, 1931.
(6) W. Fahrenbach, *Forschung* 2, 1931.

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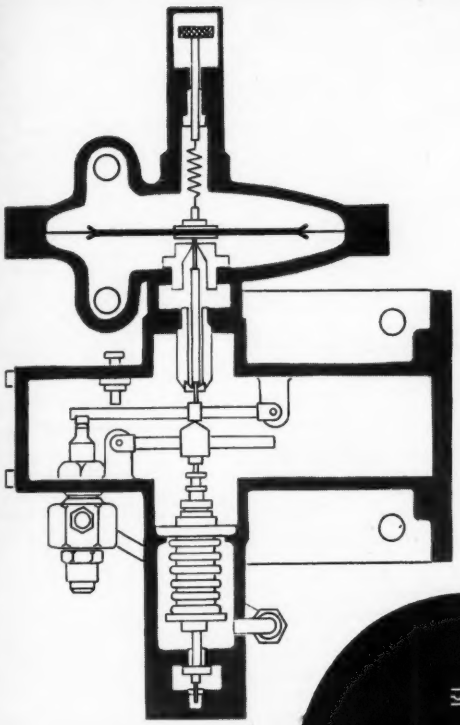

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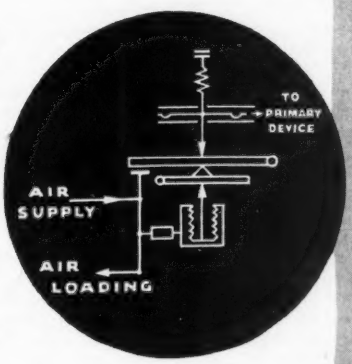

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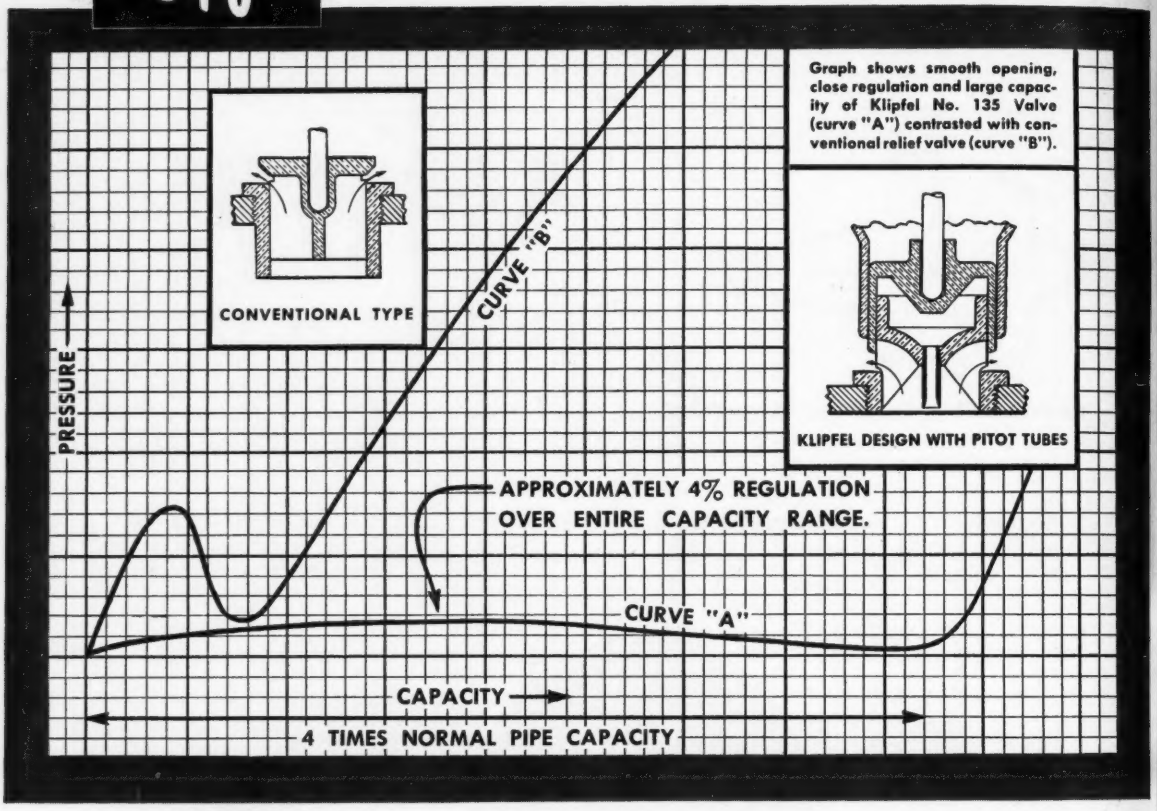
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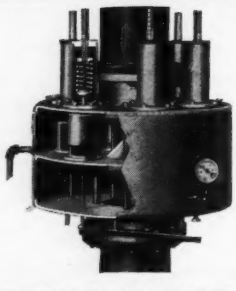

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THE SECRETARY'S PAGE

FOLLOWING is the report of the Executive Secretary as made to the Executive Committee at its meeting in the Roosevelt Hotel, in Pittsburgh, on March 30, 31, 1951.

Society Membership:

Society membership now numbers 4557. This is an increase of 259 members over the count made on September 1, 1950. (See analysis on next page.)

57 members have resigned and 200 have allowed their membership to lapse and are now inactive, (some of whom are expected to renew membership).

Fifth Anniversary Membership Campaign:

The membership campaign begun in late 1950 to extend to April 1951—planned to raise the Society membership by 15%, or to more than 5000 members, has resulted in an increase of 228 members who are definitely known to have joined as a result of campaign promotion. Final results of the campaign and awards to the Section and to the member who obtained the largest number of new members will go out in the near future.

Recommended Practices:

ISA RP3.1, "Flowmeter Installations, Seal and Condensate Chambers," is in final form ready for printing. It will be distributed, along with ISA RP4.1, "Control Valve and By-Pass Installations," to the membership in the near future.

New Speakers List:

A new speakers list has been prepared and has been distributed together with corrections and additions to the ISA Motion Picture List to Section Officers.

Report on ISA Film "Principles of Automatic Control":

This 16 mm, sound—color film had its premier showing at the Buffalo Conference in 1950. Since then, 3 copies have been procured and are now on loan-circulation from the National Office.

A descriptive leaflet on the film has been prepared and distributed to Society Officers, Secretaries and Chairmen. Approximately 1000 have been distributed to date.

In addition to 5 showings at the Buffalo Conference and approximately 5 informal showings, the film has been loaned to date, to 48 different organized groups; total showings by these groups being about 55. To date, 29 loans have been arranged to June 30, 1951; showings—approximately 37. For the period October 5, 1950—June 30, 1951: 77 loans—92 showings. Breakdown by group for this period:

ISA Sections:	19
Other Societies:	5
Educational Inst.:	10
Companies and Misc.:	43

A questionnaire sent to those who had shown the film indicated an average attendance at showings of 90. To-

tal attendance by June 30 should be well in excess of 8000.

Cooperating Societies, Houston Show:

As was the case in Buffalo, the following groups will cooperate with the ISA in the Houston Conference:

American Institute of Physics;
American Society of Mechanical Engineers, Instruments and Regulators Division;
American Institute of Electrical Engineers, Instruments and Measurements Committee;
Institute of Radio Engineers.

The following additional groups will also cooperate in putting on the Houston Conference and Exhibit:

Gulf Coast Spectrographic Society;
Texas Agricultural & Mechanical College, Instrument Symposium;

Houston University will cooperate in the Instrument Maintenance Clinic.

MEMBERSHIP OF SECTIONS, MARCH 30, 1951

Section	*Member*	*Absentee Member*	*Student Member*	*Total*
Akron	35			35
Albuquerque	31	16		47
Aruba	42			42
Atlanta	20			20
Baltimore ...	74	5		80
Baton Rouge	45			45
Boston	121			121
California ..	173			173
Central Ill. ..	37	1	1	39
Central Ind..	25	51	2	78
Charleston ..	59	4		63
Chicago	228	20	88	336
China Lake .	40	1		41
Cincinnati ..	68			68
Cleveland ..	128	4	2	134
Columbus ...	19	3	1	23
Cumberland .	16	2		18
Detroit	60	2	2	64
Eastern N. Y.	62	1	26	89
Gulf Coast .	37	2		39
Houston	140	1		141
Kansas City.	54	14		68
Louisville ...	40	5	2	47
Montreal ...	74		1	75
New Jersey.	269	1		270
Central N. Y.	31			31
New Orleans.	11			11
New York ..	195	12	65	272
Niagara Front.	70	20	4	94
North Texas.	20	1		21
No. Calif. ...	99			99
No. Indiana.	39	4	1	44
Oak Ridge .	74			74
Ontario	43	1		44
Panhandle ..	49			49
Philadelphia	313	14	13	340
Pittsburgh ..	219		28	247
Presque Isle	19	1		20
Richland ...	76	13	6	95
Rochester ..	87		1	88
Sarnia	68	9		77
So. Michigan	19	8	2	29
South Texas.	40	8	21	69
St. Louis ...	121	2	3	126
Tennessee ..	31	14		45
Toledo	39	1		40
Tulsa	90	1	1	92
Twin Cities .	27	2	2	40
Washington .	72	56		128
Wayne County	63	32		95
Wilmington .	83	2		85
At Large ...	41	4	1	44
	3936	347	274	4557

Houston Exhibit

As previously reported in these columns the Sixth National Instrument Exhibit was originally laid out for 154 booths. These 154 booths were reserved within the first 60 days of the sale of space and the continuing demand for booths required an additional 61 booths to be added, making a total of 215 booths. Of this total of 215 booths, 10 booths were set aside for the use of the Armed Services.

As of April 25, 1951, all booths have been reserved—205 booths reserved by industry exhibitors and 10 booths for the Armed Services. We have almost reached the point where it is necessary to hang out the sign SOLD OUT. However, owing to the present international situation, there is some question as to the Armed Services being able to exhibit, and some time may elapse before this question is answered. Therefore the 10 booths set aside for the Armed Services have been made available for reservation by industry exhibitors, and from the numerous inquiries still being received, these booths will be sold in the very near future. Should the Armed Services later decide to exhibit, there is still sufficient floor space available in the Exhibit Hall to take care of their needs.

The Houston Show will exceed any previous exhibit in number of exhibitors. It is to be hoped that instrument men and others interested in instruments will recognize this outstanding opportunity to see and learn of all that is important in modern instrumentation and make such plans as are necessary to be in attendance. The exhibitors will make this the *best* Show, it is up to the user to make it the *largest.*

Following is a list of the exhibitors who have made reservations since our last issue:

James G. Biddle Co.
William E. Brice Co.
Brookfield Engineering Labs.
Commercial Iron Works
Allen B. Du Mont Labs.
General Precision Lab., Inc.
Hewlett-Packard Co.
Illinois Testing Labs. Inc.
Industrial Equipment Co.
Earl Lipscomb Assoc.
Samuel Moore & Co.
Richardson Scale Co.
Sanborn Co.
Schutte & Koerting Co.
Scientific Apparatus Makers Association.
Sorensen & Co., Inc.
Herman H. Sticht Co.
Univ. of Houston
R. L. Wilson Co.
Wollensak Optical Co.

Correspondence Stickers For Houston Show

Below, reproduced in black, is the impression of the two color correspondence sticker being used to publicize the Sixth National Instrument Conference and Exhibit. The sticker is 1.5 by 2.5 inches, is red on an orange background and has been printed on gummed stock. The monument pictured is the San Jacinto Monument—Houston's memorial shrine and symbol of Texan independence. The sticker is designed for use on Society and exhibitor letters and envelopes to inform and remind interested individuals about the coming Conference and Exhibit.

Members of the Society, Section officers, program chairmen, Secretaries, etc., as well as individual members, are urged to make use of these stickers on their business correspondence. The sticker is a dignified, convenient, easily applied, inexpensive, way to promote the 'Show', instruments, instrumentation, and the Society. We will be glad to supply any interested individual with as many stickers as he can use. A post card to the National Office is all that is required.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
E. J. Burda, Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. Tel: 5-5511
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:15 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
Thomas A. Carroll, 721 Hurlburt St., Peoria 6, Ill. Tel.: Peoria 4-8909
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 Onondaga St., Syracuse.

CHARLESTON
Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M. Michelson Lab, USNOTS.

CINCINNATI
L. W. Greene, 181 Market St., Aurora, Ind.
Second Monday, 8:00 P. M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: Ex 1-5454
Fourth Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
W. C. Myers, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248

Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, 8:00 P. M., Dinner at 6:30 P. M., Algonquin Hotel.

DETROIT
A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.
May 22, "Automatic Instrumentation in Quality Control," T. S. Cawthorne, T. S. Cawthorne Co. Joint meeting with AIEE.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.
May 24, "Principles of Automatic Control," ISA Color-sound film.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., Engineers Club.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
Fred L. Crabbe, Malcolm W. Black & Co., Inc., 41 East 42nd St., New York 17, N. Y. Tel: Vanderbilt 6-2960.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:00 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.
May 23, "Refrigeration Control," Frank Salisbury, E. Kodak Co.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139
Third Monday, 8:00 P. M., E. Bay Area.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-13, Apt. 241, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. R. Trenner, Rm. 306, 3147 Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: HI 1-1800
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.
May 28, Lecture and visit to Carnegie Inst. Technology Synchro-Cyclotron; Speaker: Geo. Henman, C.I.T. **Inspection Committee:** "Legal Aspects of Procurement," Clair V. Duff of Duff, Stockdale & Doyle, Attys. at Law.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

Continued on page 594

Process Instrumentation For Crystal Growing Equipment

By S. A. HLUCHAN *

ABSTRACT. The equipment and program control system for growing single crystals of the aromatic hydrocarbons is described. The need for and use of these crystals as detection elements for scintillation type radiation instruments is treated briefly. The use of suppression voltage, thermopile activation and successive shifting of control range with time are some of the features of the control system which permit the process manipulations necessary for satisfactory product.

The equipment and control system for growing single crystals of the aromatic hydrocarbons was assembled from readily available commercial components and of easily constructed devices. This equipment consists of a crystal growing chamber, a precision oil bath and a temperature program control system. Large single crystals of anthracene have been successfully grown. These crystals were grown in cooperation with radio-chemists who needed single crystals for use in scintillation counters for radioactivity measurements.

At the start of the work the various detailed requirements and the precision of control and program for crystal growing processes for various materials were not known. Certain basic rules were known from the work of past experimenters. Perfect crystals require ideal conditions, but in practice certain compromises have to be made for reasons of speed and economy. The time required for the successful completion of a crystal run is about two weeks, so that development of growing techniques is slow at best. The equipment constructed has proven to be inexpensive, stable, and versatile in that it may be easily modified for a variety of processes, materials, and programs.

Before describing further the equipment used, some information will be given regarding the types of crystals being grown and their purpose.

In the radioactivity measurement field, continual research is being done to make faster, more efficient and longer lasting radiation detecting elements. For this purpose in recent years many natural and synthetic crystals have been investigated. The advantages of crystal counters over the more conventional type detection elements are that their smaller size makes possible better measuring geometries, they have high stopping power (particularly important in the case of gamma radiation), they have low resolving times (making possible high speed counting and fast coincidence measurements), they have long life and are also valuable in certain special applications, such as measurements of particle energy. These crystals are used with counting, coincidence and spectrometer circuits.

The crystals grown were for the "scintillation" type of radiation measuring instruments. A "scintillation" crystal scintillates or emits thousands of tiny flashes of light when exposed to a radioactive source giving off alpha, beta, or gamma radiation. This phenomenon is called fluorescence. The crystal extracts energy from incident particles and re-emits pulses of light of a characteristic wave length. There is a fluorescent light pulse for each incident particle within the crystal.

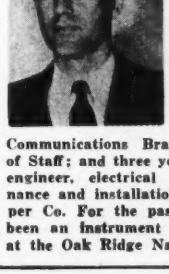
To demonstrate this property of fluorescence, we bring a crystal of anthracene near a source of, say, ultraviolet light. We notice that it glows strongly with a fluorescent radiation in the visible blue color range. This blue color (wavelength 4400 A.U.) is characteristic of anthracene and of the incident radiation.

The most striking optical property of a single crystal of anthracene is that of double refraction. Fig. 1 is a photograph of a crystal of anthracene placed on top of a single ruled line and a set of letters on a piece of paper. It demonstrates crystal clarity and double refraction. It has the required shape and size (2 in. O.D. x ¾ in.) for a scintillation counter photo tube (RCA type 5819) window. The orientation of the crystal was such that maximum image separation had occurred. Further rotation in either direction would merge the two images.

The final and most rigorous test for a crystal is by its performance in a scintillation counter or spectrometer. Various crystals can be compared according to the height of pulses produced at the amplifier and by their ability to resolve energy maxima in the

THE AUTHOR

S. A. Hluchan, graduated from Oberlin College in 1935 with majors in Physics and Mathematics, received M.S. in 1938 from the University of Cincinnati where he majored in Physics and Electrical Engineering. Hluchan's experience includes three years as physicist in charge of instruments and automatic controls at the Champion Paper & Fiber Co.; four years as radio engineer and physicist, doing ionospheric-magnetic overseas research for Communications Branch of Joint Chiefs of Staff; and three years as assistant plant engineer, electrical and general maintenance and installation, at the Beckett Paper Co. For the past three years he has been an instrument development engineer at the Oak Ridge National Laboratory.



*Instrument Department, Oak Ridge National Laboratory, Oak Ridge, Tenn.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y. Sept. 12-18, 1950.

Statements and opinions expressed in these articles are those of the authors and not necessarily those of the Society.

Fig. 1 Crystal Showing Double Refraction

spectra of certain standard radioactive sources. A crystal may be optically perfect, but still be inferior in actual performance in an instrument to another crystal much less perfect in visual appearance. This may be due to a trace of impurity or the presence of some decomposition product. In the case of the crystal sodium iodide, for example, performance is improved by the presence of a trace of thallium.

Crystal growing is nearly as much an art as it is a science. Usually it is a practical compromise between what is ideally required for perfection and what is economically possible within a reasonable period of time. In nature, nearly perfect crystals like the diamond had taken an extremely long time to form and cool. There nearly all conditions were good except for possible presence of impurities. Basically the conditions necessary were mononucleation (single seeding), a long time interval for cooling, freedom from impurities, and no decomposition of the original material. The difficulty with which crystals of different materials can be grown varies greatly. Some crystals, for example sodium iodide, can be grown easily while others such as anthracene are rather difficult to grow.

The two methods of growing crystals giving most consistent and successful results have been variations of the method of condensation from the vapor state. In both cases the anthracene was placed in the bottom of an evacuated growing chamber which has a controllable cold ceiling containing a seed crystal. In one method, crystallization in the presence of refluxing, the anthracene melt was held at 218° C or slightly above its melting point. In the other method, a simple sublimation process, the temperature of the anthracene mass was raised to only about 195° C, or just above the supercooling temperature of anthracene on mica, which covers the ceiling. To start crystal growth, the ceiling of the chamber is slowly cooled until all the raw material has been sublimed and condensed on the ceiling. Annealing followed by a cooling to room temperature completes the process. Hence, the basic steps in these processes were nucleation, growing or forming, annealing, and cooling to room temperature.

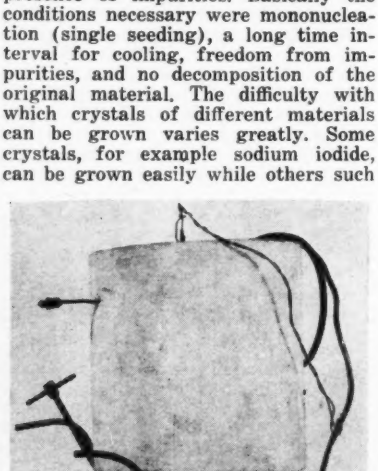


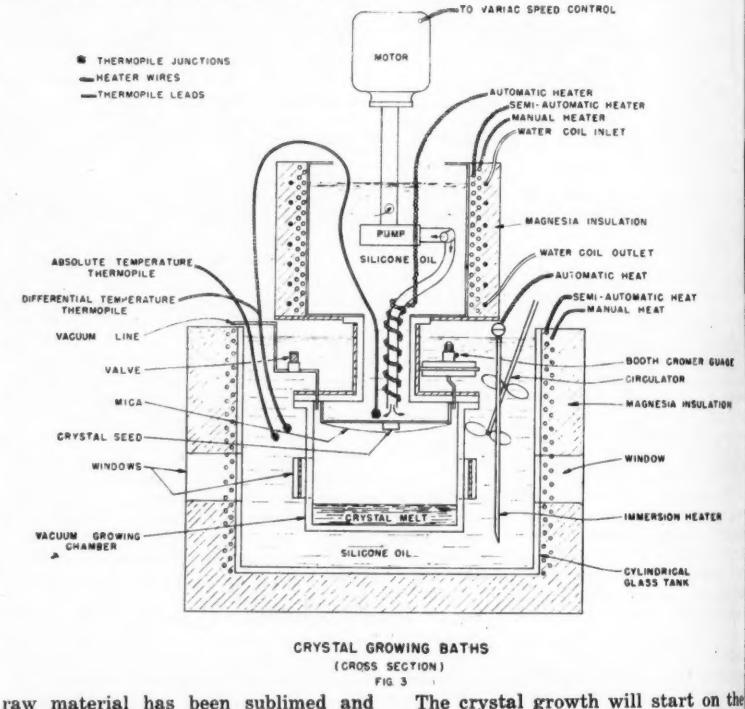
Fig. 2 Growing Chamber and Upper Bath

It was hoped that in this crystal growing process decomposition of anthracene would be minimized and contaminating materials would remain in the residue on the floor of the chamber.

The growing chamber with upper bath attached is shown in Fig. 2. Its operation is better illustrated by cross-section sketch Fig. 3. The lower circular chamber with two windows is the crystal growing space. The upper part is just a vessel for containing the cooling bath oil and the submerged circulating pump. The growing chamber is entirely submerged in the lower bath oil during operation.

The lower chamber fastens to the ceiling (which is a part of the upper vessel) by means of flanged connections containing a gasket.

On the side of the lower chamber are two diametrically opposite windows, one for illuminating and one for viewing. Evacuation is achieved through a line containing a valve and passing through the edge of the ceiling. By means of a similarly located line a modified Booth Cromer gauge is connected to the growing chamber to make possible pressure measurement at any time. Both valve and gauge are covered by the lower bath oil to prevent condensation of vapors into the working parts. On the bottom of this chamber is the crystal material. The ceiling directly above is covered by a circular plate of thin mica with a 3/8 in. hole in the center. This plate is held at the edges and helps support the prepared seed which is cemented to the brass ceiling directly over the hole in the mica plate.



CRYSTAL GROWING BATHS
(CROSS SECTION)
FIG. 3

The crystal growth will start on the seed and gradually spread over the entire mica surface. The crystal mass grown upon the mica plate separates away from it during cooling and is then only supported by the material in the center hole and a thin edge at the periphery. Anthracene super-cools on mica at a much lower temperature than on metal so the the presence of a good seed at the start of the growing process must be certain.

An oil bath rather then an air oven was chosen because of its inherent advantage in stability, large supply capacity, temperature uniformity capabilities ,good heat transfer qualities, controllability by simpler instruments, reduction of measurement and transfer lags, and good diffusion ability in wiping out unwanted gradients and promoting the desired gradient in the growing surface.

The choice and arrangements of parts was such as to promote ease of precise control. Reference to Fig. 3 is again made to note some of these details.

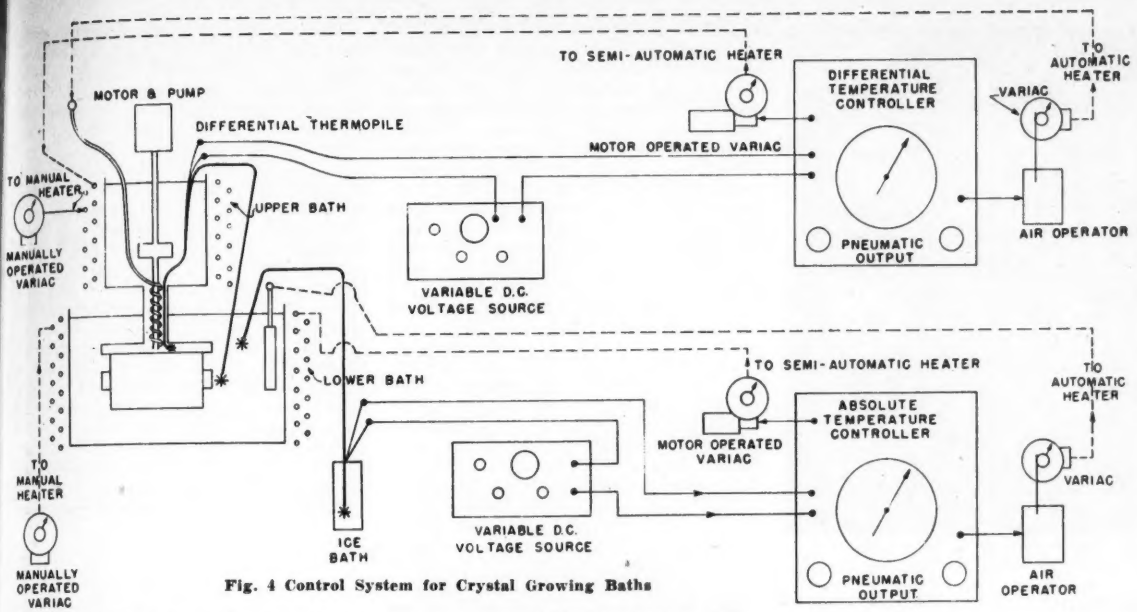


Fig. 4 Control System for Crystal Growing Baths

Rapid oil circulation in both the horizontal and the vertical directions was achieved in both baths. In the upper bath oil was taken by the submerged centrifugal pump from near the top and then a small portion was discharged in the horizontal direction and the larger portion was carried by a long pipe directly to the cooled ceiling of the chamber. The lower bath was circulated by means of a stirrer with separated double propellers immersed at a large angle from the vertical in order to impart both vertical and horizontal motions to the fluid. Since both bath and growing chamber were circular in shape, and the circulation rapid, there are only negligible zones of fluid stagnation. A variac was used to control pump speed. This was necessary because of vicosity changes in the bath oil produced by temperature changes during the process.

The manual and semi-automatic heats were applied uniformly and spread over the entire side wall surfaces for both the upper and lower baths. These two types of heaters supply usually from 60 to 80 per cent of the heat required while the additional amount required was made up by the automatic heater. Each heating unit was wound non-inductively and had separate lead wires.

The automatic heaters were low lag immersion heaters located upstream just before the temperature measuring element in each case. For the upper bath the heater is wound non-inductively directly on the end of the copper discharge pipe from the centrifugal pump. In the lower two knife type immersion heaters were used. The maximum safe heat dissipation of this heater under these conditions was 15 watts per square inch. The automatic heaters have negligible supply capacities and a rapid heat transfer ability. The maximum heat demanded by the process was during the end of the growing stage when the temperature differential between ceiling and melt was greatest. The power required at that time was about 1.5 kilowatts.

The use of non-inductive heaters was to minimize possibility of stray a.c. voltages being picked-up by the nearby temperature measuring element and affecting the operation of the measuring instrument, an electronic potentiometer.

Nearby downstream from the automatic heaters were located the thermopile junctions. These are small gauge bare thermocouple junctions, capable of rapid response to temperature changes. In cases of both lower and upper baths the radiant heat seen by the thermopile was very small because of placement of heaters. However, the direct viewing of the radiant surface by the thermopile might speed up and improve the detection of temperature changes. Although this might produce faster and greater cycling in the short space between heater and detector, the mean temperature of the main body of the bath might be held to a better average. This usually requires two measuring elements, one for control and the other for measurement. It must be emphasized that the temperature element should not be located immediately next to the heater. If such were the case, it would not indicate either the demand or the supply temperature, but some value in between. The changes in demand temperature would tend to be masked by the supply temperature changes.

If the temperature cycling at the point of measurement in the bath is rapid and of small amplitude, then the temperature of crystal growing surface within the chamber will vary even less because of the lagging action of the intervening walls.

Connecting the thermopiles to recorder-controllers of high sensitivity and small dead zone completed the control system. The controllers and their output mechanisms will be discussed in a later section.

The final assembly of this bath required certain special materials which will be discussed briefly at this point. A few of these were the bath liquid, high temperature electrical insulating material and gasket material.

The bath oil finally used was Dow Corning's silicone oil d.c. 550. Another silicone oil was tried earlier polymerized after two days' operation at 230° C. The oil used was fortified by the addition of a small amount of a stabilizer, para-aminophenol. When operating at 250° C. or higher some vapors issue from the bath and the equipment should be used under a ventilating hood. At this temperature too, more frequent use of the stabilizer is necessary. The stabilizer tends to darken the solution which however, again clarifies with continued use at high temperatures.

The gaskets for the windows and chamber flanges are teflon washers. This material is satisfactory but tends to flow and warp under pressure at the higher temperatures if not uniformly confined.

Teflon ribbon, fiber glass sleeving and mica were used for electrical insulation on heaters and thermopile wires.

It was estimated that the control system should be sensitive to better than a 0.1° C. temperature change. A controller with adjustable sensitivity and reset actions was decided on, because of the variety of materials to be worked with, different process conditions and manipulations, and the wide temperature ranges to be encountered. A controller with pneumatic output was considered particularly appropriate because of the flexibility and adaptability of air power to various types and sizes of control mechanisms. Wide range adjustments on the controller sensitivity and reset rate would make possible tuning in the controller on different system arrangements. Derivative action was not considered necessary. The controller had to be stable and operative for several weeks at a time and through a variety of program changes.

These crystal growing processes do

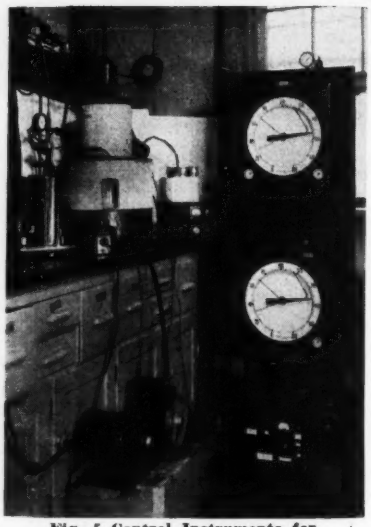


Fig. 5 Control Instruments for Crystal Growing Bath

not require that the absolute value of the temperature of the melt be known to much better than about 1° C, since the process is usually carried through a safe range of temperatures. It is important however, that all temperature changes be small and slow, particularly during the critical growing period. Sudden large changes in temperature are very harmful to the process. Slow small temperature changes spread out over a number of hours resulting from drift in some electrical component will merely alter the growing rate slightly. The measuring element chosen was a thermopile of ten junctions. It has rapid response, sufficient accuracy and is easily matched to the controller and, more important still, readily used in conjunction with a simple but highly versatile program controller. Ten junctions in this pile do give such a voltage output that the controller has sufficient signal to control to ± .1° C. Use of the thermopile necessitates the use of a reference junction ice bath and a suppression voltage source.

If one had unlimited choice of measuring and controlling instruments, the optimum number of couples for a thermopile would be determined from the accuracy and sensitivity of the available measuring device, the sensitivity of its control system, the constancy with which the reference junction temperature can be held, and the lack of drift or fluctuation in the suppression voltage.

The components were so chosen and designed that control of the bath to ± .1° C. would be possible during the critical growing period. Requirements for the annealing and cooling stages are less stringent.

The general operation and arrangement of the controls are illustrated by block diagram Fig. 4.

The lower bath temperature was measured by reading the output voltage of a 10 junction thermopile whose cold junctions are immersed in an ice bath. Connected in series opposition with this is the variable suppression voltage. The difference voltage is applied to an electronic potentiometer recorder-controller of a fixed span of 3 mv. This controller has a pneumatic output, which positions a variac controlling the voltage to the immersion heaters by means of a diaphragm operator.

The upper bath temperature was forced to allow the lower bath temperature by a pre-determined offset because of the differential thermopile connection between the two. The magnitude of temperature separation was determined by adjustment of the variable suppression voltage in series opposition with the thermopile output. The difference voltage of these two units was applied to a recorder-controller identical to the one used for the lower bath. Any change in the desired temperature differential is corrected by controller voltage adjustment to the heater wound on pump discharge pipe. Fig. 5 shows the equipment and controls as assembled for a crystal run.

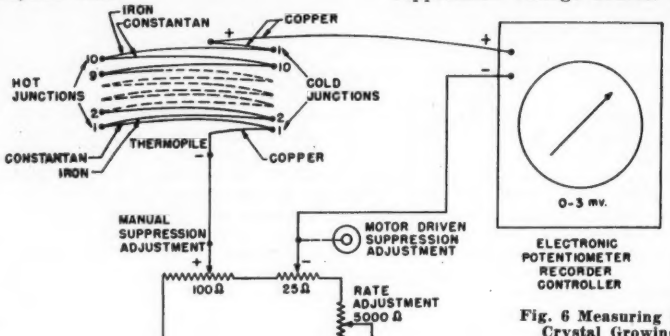


Fig. 6 Measuring Circuit for Crystal Growing Baths

The components and devices of the measuring and controlling systems for the upper and lower baths were similar in design and operation, differing only in operating ranges and output values. Therefore we shall discuss the units or components separately without reference to their location except when necessary to bring out differences.

The temperature sensing elements were bare junction thermopiles. Each thermopile was comprised of ten junctions of number 25 gauge iron and constantan wire. The separating insulation was fiber glass sleeving. The zero of the differential thermopile was determined by immersing both junctions in a light oil in a Dewar flash and reading the resulting small voltage on a potentiometer after agitation had produced equilibrium. The thermopiles are immersed bare in the bath oil and down stream from the immersion heaters so shielded as not to be exposed to the direct radiation of the immersion heaters. This thermopile is very sensitive to radiation. Accidently shining the illuminating lamp on its junction quickly sends the recorder off scale. The absolute thermopile used checked to better than .1° C. against a standard resistance thermometer. Two suppression voltage sources are required, one for the absolute temperature controller and the other for the differential temperature controller. They were identical in construction. Their operation is illustrated by Fig. 6.

The adjustment marked "rate" controls the current flow through the three helipot potentiometers. The first helipot marked "manual suppression" is for making large voltage suppression changes at high temperatures. The second helipot marked "automatic suppression" is a ten turn helipot powered by a reversible motor. The motor drives the helipot shaft through a friction clutch and lock nut mounted on the front panel. The helipot has a fixed travel rate of one turn per day. By means of these adjustments and the reversing switch on the motor the temperature or temperature difference can be caused to increase or decrease through any temperature range for a maximum period of ten days at any required temperature rate. Nearly the same care and principles of good construction that are observed in the assembly of a precision potentiometer are necessary in the construction of a suppression voltage source. The chief differences being that absolute accuracy is not needed and also that slow drifting (about .05 mv. per hour) would not interfer with the temperature program control. No difficulty was encountered in meeting these requirements. Since this device is operating continuously for long periods of time it must have large capacity constant potential batteries to minimize voltage drop due to battery drain. The parts of this device which are slightly temperature sensitive are protected against ambient temperature changes by an internal thermostat, small lamp heaters and insulation.

Either the "Le Carbon" battery (air cell) or the Columbia Gray Label battery are excellent components. The current drain from these batteries is usually about 1 ma. and the maximum about 15 ma. All the d.c. lines and components were carefully separated and shielded from the a.c. lines and

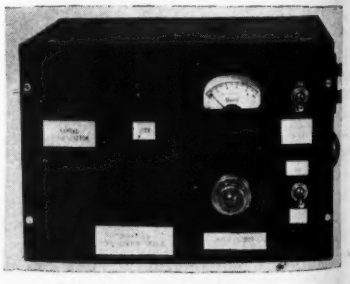


Fig. 7 Variable Suppression Voltage Unit

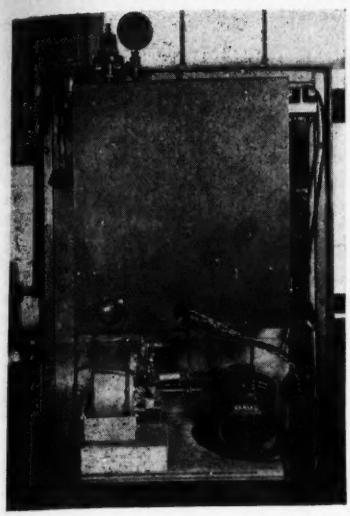


Fig. 8 Pneumatic Operator for Variac

components. This was to remove possibility of a.c. "pickup." The battery and helipots which were to be held at constant temperature were enclosed by a metal cover. The thermostat and heater were located in the outer space with the motor. Precision resistors and helipot slide wire potentiometers were used in these units. Protection against battery drain and against ambient temperature changes were points of most importance in designing these suppression units. The appearance of a completed unit is shown in Fig. 7.

The instruments used for measuring the difference between the thermopile and the suppression source voltage are circular chart electronic potentiometers. The range in each case is 3 millivolts. With ten junction iron-constantan thermopiles this represents a temperature span of 5.45° C. The chart has 100 uniform divisions. The recorder for the absolute temperature thermopile (in lower bath) was calibrated with zero millivolts with pen at chart zero. The recorder for the differential thermopile however has a suppressed zero, so that zero on the chart corresponds to —2.0 millivolts and full scale to + 1.0 millivolts. The control point then in either case would be set at some arbitrary value well up scale and then the actual operating temperature or the temperature differential achieved through adjustment of the corresponding suppression voltage.

These recorders have a pneumatic control output whose maximum air pressure usually carries about 30 per

Fig. 9 Motor Driven Variac

cent of the total heating load. Both controllers have adjustable control sensitivity and reset rates. Settings on the throttling range were from 4 to 10 per cent. A small amount of reset action was also required. The pneumatic output of the controller was mechanically converted into an electrical voltage change by a device mounted behind the controller case. Fig. 8 shows one of these units. The controller air output pressure was applied to a bellows operator which had a positioner air-relay built into it. The linear motion of a rod from this operator drives a rack across a gear mounted on the brush shaft of the variac causing the brush arm to rotate a 3 to 15 psi. pressure change will produce a full rotation of the variac. The voltage from these variacs supplies the immersion heaters in the baths which we've referred to as the automatic heaters.

After the throttling range and reset rate adjustments were found, it was possible to set the control cam contacts to 5 per cent above and 5 per cent below the control point. The actuation of these contacts causes a reversible motor mounted on a variac to either increase or decrease the voltage on the semi-automatic heaters. The motor drives the variac brush through a friction clutch at the rate of a full span rotation in 80 minutes. This device only functions during the more rapid and less critical stages of the process. For it to operate the automatic heat variac must have reached its limit of rotation and the temperatures have drifted 5 per cent above or below the control point. During the day time the operator seeing any control variac near its limit of travel would make a compensating adjustment on the complementary, manual or semi-automatic variac. Fig. 9 shows one of these semi-automatic variac drive units.

A record of the kind of control possible with this equipment is shown by Fig. 10 and 11. Fig. 10 shows a day's record of temperatures in the lower and upper bath during the critical growing period. The lower bath was fixed at 220° C. and the upper bath was cooling at the rate of 0.2° C. per hour. The temperature difference between the upper and lower bath was 10° C. at the end of the day. Fig. 11 shows two examples of the semi-automatic heater coming into operation and bringing the temperature back into the control zone of the automatic heater.

This equipment was designed for ex-

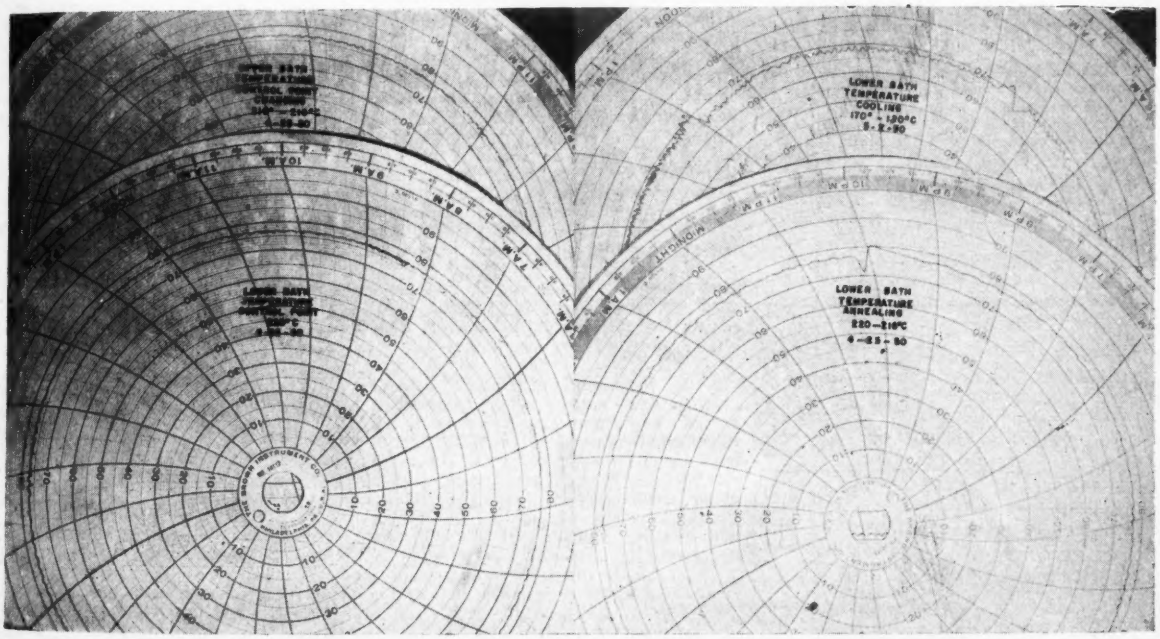


Fig. 10

Fig. 11

perimental work rather than for routine production of crystals. It is being used to advance the art of growing crystals of different materials by various methods. As the use and information about crystals and their associated instruments in radioactivity measurements increase, purer materials and more nearly perfect crystals will have to be produced.

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Automatic Control of Flow in the Process Industries

By A. E. Krogh*

Abstract. The author graphically demonstrates the relative time requirements for control recovery with mechanical, electrical, and diaphragm type transmitters and their location in relation to controllers. He discusses the desirability of control devices receiving undamped signals and advocates that sensing element operating the controller be independent of that operating the recording pen. Expected improvement with changes of distance between transmitters and controllers are analyzed, being relatively small for tubing distances less than 400 feet but increasing rapidly above this distance.

THE HISTORY of instrumentation has been one of continuous probing into possibilities of finding means for measurement and control of new variables and of discovering improved means for measuring the old variables and controlling them. It is in fact a keystone of industrial and scientific progress in this country and throughout the world.

In these days instrument engineers are generally not satisfied merely to measure a variable but also want to apply automatic control. As new or improved means for measurement are found, the possibilities of consequent improvement of automatic control need to be explored in each instance. Oftentimes the success of the venture is dependent entirely upon the automatic control principles applied with the measuring means to produce over-all success. Tailoring of control systems to fit the specific characteristics of a measuring device can often make the difference between success and mediocrity.

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NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

The automatic control instruments and devices with which we are so familiar today were developed and perfected in the last three decades largely in the work done to accomplish flow control. As such, they have been based upon the use of U-tube type meters measuring the differential pressures created by flow through primary elements, such as orifices, nozzles, and venturi tubes. In passing, it is perhaps worth noting that, while these primary elements have many shortcomings, this method yet remains the most practical and generally adequate means of creating a measurable response to flow, partially because of the great volume of reliable data available on co-efficients.

Diverse Approaches to Flow Problem

A study of basic flow-metering methods made by us some six years ago revealed some 30 basically different ideas proposed by various people in the years gone by to which our research men and technicians added a number of others. Some of these were further explored by our research men. The gains possible from these other methods were quite limited and in any case were not sufficiently attractive to warrant the extensive work needed to set up new coefficients. There were, however, possibilities of finding additional means of measuring the differentials created by the primary devices. The mercury-filled U-tube is, after all, relatively ancient in the history of instrumentation. It will likely continue to be the standard differential measuring means.

THE AUTHOR

A. E. Krogh attended Carnegie Institute of Technology, receiving his B. S. degree in Physics in 1925. He joined The Brown Instrument Company in Philadelphia upon graduation and has completed 25 years of service in the Engineering Dep't of that organization. Throughout this period he has been active in application engineering studies, involving a great deal of actual field work in measurement and automatic control problems in many types of industries. He is at present Manager of the Product and Application Engineering Division, Brown Instruments Division of Minneapolis-Honeywell Regulator Co., Philadelphia.

A desire to get away from mercury-filled U-tube meters has always existed in chemical industries, particularly on those applications where corrosion and sludge were major factors. On such installations, maintenance of seals and of meter bodies has been very troublesome. Thus, these users have been and are very receptive to any devices which promise to improve the situation materially, even at some sacrifices of accuracy and/or reproducibility.

Variable-area meters have earned for themselves a well deserved place in these industries because of their relative freedom from corrosion troubles and are now available with recording instruments and automatic control. They have not, however, been generally acceptable as a complete answer for many applications.

Use of Mercuryless Meters

The use of bellows-type meters in flow measurement also goes back a good many years, and several commercial forms were on the market in the early 30's. They were generally considered of inferior accuracy until additional forms appeared just prior to the beginning of the war. The latter forms employed torque-tube transmission and had many desirable features. They were, however, frequently in trouble especially when used as automatic controllers.

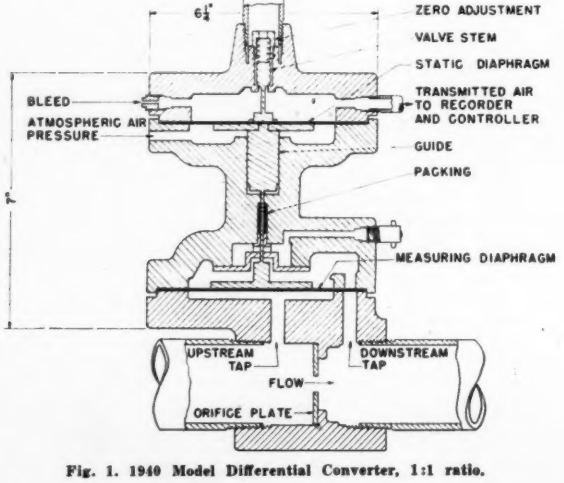

Fig. 1. 1940 Model Differential Converter, 1:1 ratio.

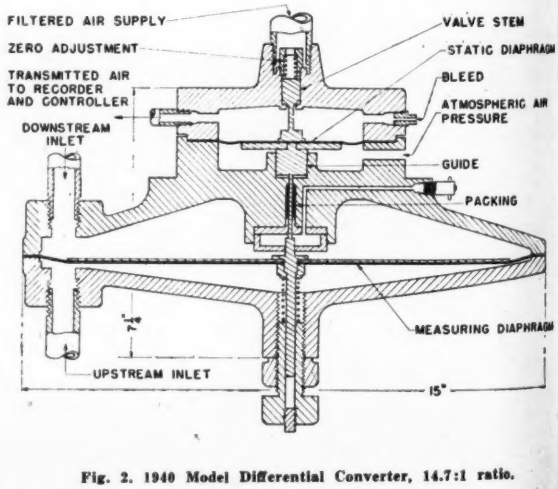

Fig. 2. 1940 Model Differential Converter, 14.7:1 ratio.

It is believed that at least some of the blame for this situation rests upon a necessity for re-examination of the control devices when new measuring devices of radically different behavior are applied, as in this instance. Some of the attempts made to overcome the difficulties increased the complexities of the over-all system to a harmful degree. A more basic approach was indicated.

Other forms of mercuryless differential measuring means have been in use for many years. My own company made and sold a large number of what we called Differential Static Converters in the period of 1935 to 1940. These devices are illustrated in Figs. 1 and 2.

These units were quite successful though they lacked complete facilities

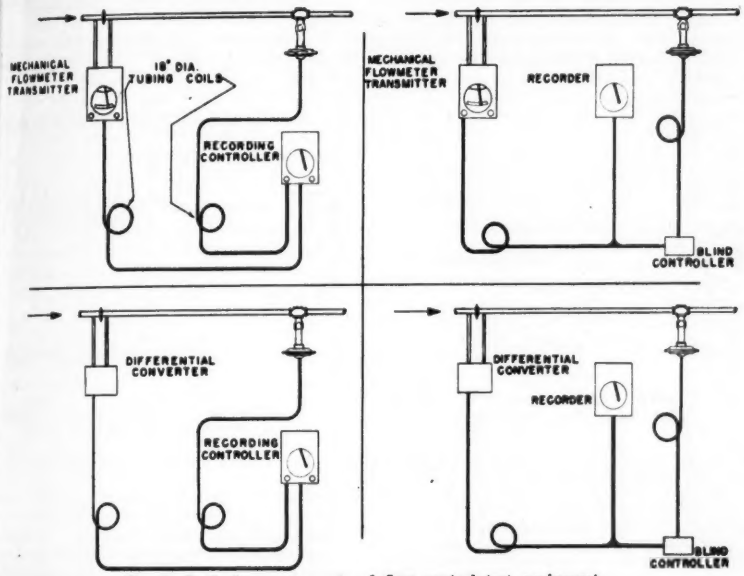

Fig. 3. Typical arrangements of flow control test equipment.

for calibration and adjustments. They were however, entirely dependent upon the supply of compressed air. When that supply became dirty or failed, the system was unworkable. These shortcomings were considered serious enough to discontinue this work for, in such meters, no flow indication can be had unless the air supply is continuous. In many plants the air supply was quite unreliable.

In the last decade there has been much improvement in the reliability of supply air for instruments and this is particularly true in chemical plants and refineries. Today therefore we now find users in such plants amenable to sensing devices dependent upon this external power for their indication.

The way seems open, therefore, for manufacturers to perfect pneumatic transmission devices of this type. Some such devices are already available, and we shall undoubtedly see additional differential converter units on the market.

Sensitivity in Flow Measurement

A characteristic of both bellows-type and diaphragm-type differential meters is their inherent high sensitivity. They tend to respond to each and every small disturbance in the line. Since the flow in many lines is turbulent in some degree, the effect is that we measure a lot of "hash" or "noise", to use the terms of the electronic trade. To some extent these effects have always been giving trouble and most mercury U-tube meters are equipped with restriction means to partially overcome the problem. On mercuryless meters, however, the difficulties are increased due to their low inertia.

It is possible to decrease the sensitivity of bellows and diaphragm meters. The liquid-filled bellows-type sealed meter is an example of such possibilities. When so restricted, these meters behave very similarly to mercury-type meters, but many dry meters do not have such facilities and probably should not have them for reasons of automatic control.

In these meters, the high response speed causes a recording pen to create a paint-brush effect which is neither pretty nor useful and which imposes harmful, useless wear on the instrument as well as on the observer's eyes. To overcome this, the usual procedure is to restrict the transmission line. Where the flow is noisy, this restriction must be pretty tight.

Now, it is one thing to restrict the measuring device in order to assure that the indication is readable and that the record line lose its "paint-brush" appearance. It is quite another thing when the restriction is inserted into an automatic control servo-loop. We must not forget that in a servo-loop the sensing and transmission system is as much a part of the control system as the control valve and the process itself.

Certainly, many have had the experience of learning that the setting of the controller adjustments and that of the meter body restriction were interdependent, i.e., the tighter the measuring system restriction, the more one needed to reduce the proportional band, and so on. With low inertia systems this difficulty is even more pronounced. In spite of all this, the operator still needs a damped instrument.

It is a cardinal principle of automatic control that high speed in detecting variations and the application of remedial steps will tend to improve results in terms of holding the variable to the desired value. In some applications this can be over-done and can cause disturbances elsewhere in the process which it sometimes is more important to avoid than the holding of the variable under control. Nevertheless, it is generally true that the sooner a deviation is detected and corrective action applied the better the variable will be held.

Our controller therefore should have an unrestricted response to the transmitter signals while the recorder should be damped. Also, when highly sensitive measuring devices are employed, the controller function should be separated from the recorder function. The use of pneumatic or electric transmission in the measuring system lends itself beautifully to such separation.

In separating the control function from the recording function, we are able to take advantage of the increased response speed of the detecting system and we also gain the ability to locate the controlling mechanism where we choose. We may locate it at the valve or at the control board or anywhere else within the practical limits of transmitting pneumatic intelligence. To determine the effect of locating the controller at various distances from the valve, a series of tests were made by us.

Tests of Flow Control Systems

The tests were carried out by installing a hydraulic system, including a pump, an upsetting valve capable of sudden adjustments, an orifice, and a control valve without positioner, in series in a loop beginning and terminating in a reservoir under atmospheric pressure. The system was supplied with water, and a continuous "noise" disturbance equivalent to about two percent was imposed by the pump operating at about 40 psi.

The differential created was simultaneously measured by means of the following systems, each calibrated for 100 inches water differential:

(a) an indicating mechanical flow meter transmitter connected to a pneumatic receiving instrument,

(b) an inductance bridge type flow meter transmitter and receiving instrument,

(c) a blind differential converter of diaphragm type wherein the pressure differential is balanced by the output pressure which in turn was measured on a pneumatic receiving instrument.

No restrictions were applied in the U-tubes, the connecting lines, or in the recorders. The latter were equipped with high-speed chart drives to facilitate analyses of the records obtained.

Tubing was coiled in 18-inch diameter loops and all joints were tested when made. Automatic control was accomplished by blind pneumatic controllers and alternately by recording controllers. In the case of the inductance bridge, the latter is the only practicable system.

No valve positioner was used since flow control field installations are believed to be without them in most cases. Fig. 3 shows schematically the types of systems tested.

Test Results

Many hundreds of tests were made. The fact was verified that the use of a mercuryless transmitter with unre-

stricted pneumatic transmission to a controller makes it possible to correct a 15 percent change in flow considerably faster than a mechanical transmitter system can with the same controller in the same location. While this criteria of recovery time is not used in most textbooks and articles on automatic control theory, it is significant here and deserves mention. Some of the data obtained is illustrated in Fig. 4.

Starting from a base with which many are familiar, such as the behavior of a mechanical-meter transmission system with the receiver-controller located 160 feet from the transmitter and from the valve, note that there is nearly 80 percent reduction in time when a diaphragm transmitter is substituted for the mechanical meter. When a locally-mounted controller is used, there is a further reduction of about 12 percent.

The electric and mechanical transmitters exhibit identical behavior in respect to recovery time when controllers are locally mounted but differ greatly, as could be expected at greater distances. Note how relatively flat the curve is for systems using electric transmission. It is much less affected by distance than the other types.

A more commonly used basis for comparison is that of relative areas under recovery curves. We are not fully convinced that this is a better basis in this instance, since operators are basically concerned with speed of recovery; but the final results are similar on either basis, and we shall conform to conventional practice. The recovery curves were in each instance produced by a recorder connected to the controlling transmitter.

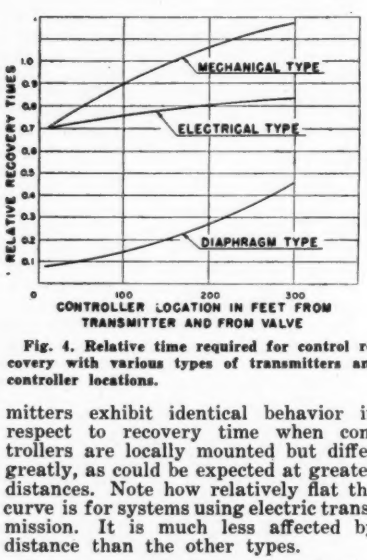

Fig. 4. Relative time required for control recovery with various types of transmitters and controller locations.

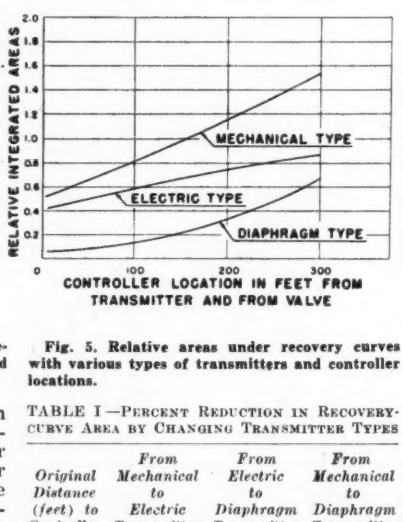

Fig. 5. Relative areas under recovery curves with various types of transmitters and controller locations.

Analysis of Recovery Curves

Fig. 5 shows a set of data similar to the preceding but now illustrating the relative areas under each recovery curve. Note that in all cases there is an increase in area with increased distance. Note again the nature of the curve for the electric meter. As the distance is increased, this curve rises only slowly. We believe this due to the fact that, when electric transmission is used on one side, the effective lag increase with increase in tubing is only one half that for systems using pneumatic transmission throughout.

Fig. 6 illustrates in a different manner the improvements obtainable by the use of diaphragm-type transmitters. Note that for locally-mounted installations the improvement of diaphragm transmitting systems over mechanical transmitters is of the order of 90 percent, while for panel-mounted installations at 200 feet distance it is about 75 percent, and at 300 feet it is only 56 percent.

The electric transmitter shows less improvement over the mechanical when locally mounted as we would expect since both are lagged by the inertia of mercury. However, when distances increase, the electric transmission tends to offset the mercury inertia and at 300 feet the electric and the diaphragm types approach each other rather closely. The two systems appear to have equal lags at about 350 feet.

Additional conclusions can be drawn from this data to show the relative improvement possible in changing from one type transmitter to another and in changing controller locations. (See tables I and II).

TABLE I—Percent Reduction in Recovery-Curve Area by Changing Transmitter Types

Original Distance (feet) to Controller	*From Mechanical to Electric Transmitter*	*From Electric to Diaphragm Transmitter*	*From Mechanical to Diaphragm Transmitter*
5	21	90	92
160	31	68	78
300	44	22	56

TABLE II—Added Percent Improvement by Additionally Changing to Controller Distance of Five Feet

Former Distance (feet) to Controller	*From Mechanical to Electric Transmitter*	*From Electric to Diaphragm Transmitter*	*From Mechanical to Diaphragm Transmitter*
160	(See note)	22	14
300	(See note)	68	36

Note—Electric Transmitters not readily adaptable to controllers mounted apart from receiving instruments.

We have concluded that the use of high-sensitivity mercuryless transmitters represents the major improvement and that the additional gain possible by mounting the controller nearer the valve is of lesser magnitude. Furthermore, it may in some ways be undesirable.

Our firm recently interviewed a large number of representative users of flow control in the chemical and petroleum process industries. Among the questions asked was "What should a good flow control system do better than those now available?" The answers were unanimously to the effect that the conventional systems were generally adequate from the functional standpoint though decrease in maintenance was frequently named as very desirable.

Only a few of those with whom the problem was discussed went further and named as a criterion of flow control the ability of a system to recover from an upset with a minimum area under the recovery curve. In today's processes there are only few places where the difference in recovery time between the conventional system of, say, 15 seconds and the minimum of, say, 1.5 seconds obtainable with the new systems would be noticeable either in the process or on the chart (particularly since recording pens will invariably be damped).

Under these circumstances, why are we then concerned with improvements such as these? The answer is, of course, that our search for improvement must never stop. The day when process engineers will be unable to utilize improved control systems is not likely to be within the liftetime of any of us, in spite of some gloomy prophets abroad in the land. Care must be employed, however, to assure that the improvements are real and that we do not just change for the sake of change.

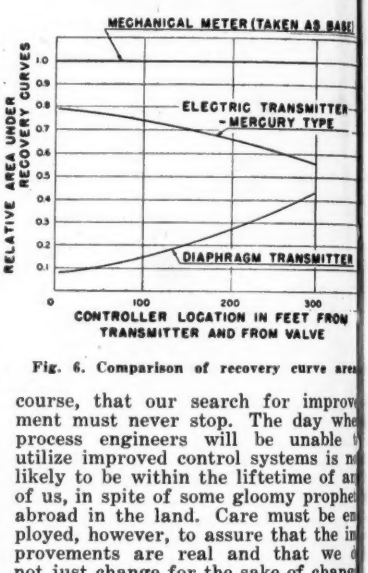
MECHANICAL METER (TAKEN AS BASE)
RELATIVE AREA UNDER RECOVERY CURVES
ELECTRIC TRANSMITTER - MERCURY TYPE
DIAPHRAGM TRANSMITTER
CONTROLLER LOCATION IN FEET FROM TRANSMITTER AND FROM VALVE

Fig. 6. Comparison of recovery curve area

Observations on Results of Test and Survey

For the present, it seems clear that where pneumatic transmission is to be used, mercuryless transmitters are advantageous and increased response speed is not harmful in control systems. For the future, it seems possible that process designers may, by virtue of the faster operation characteristics of new control systems, be able to reduce storage volume somewhat in future designs. For the time being, this seems fairly theoretical.

In respect to controllers and the preferred location for these, we find that for maximum speed of recovery the distance from the sensing element through the controller to the diaphragm valve must be minimum. For practical purposes, however, the speed of recovery will be adequately fast when the total distance is less than 400 feet (i.e., 200 feet in each direction) and thus a control mechanism located in an instrument house up to 200 feet from the orifice and valve will do an excellent job and more than four-fifths (75/92) of the possible improvement will be attained.

Since most control valves are within

200 feet of their control houses, we consider this important from two standpoints:

(1) Instrument engineers have worked diligently for many years to have control equipment located within instrument houses for ease of adjustment and maintenance. We see little purpose in giving up this accomplishment for a theoretical improvement. In a good many cases it seems one may have his cake and eat it too.

(2) We have pointed out the near necessity of having the recording function separated from the controller in these systems. This in turn requires that a set-point signal must be sent from the instrument board to the controller even if the latter be located directly behind the panel. This and the need for panel-mounted by-pass facilities in turn requires the use of four copper tubes from the board to the controller, but these tubes can be short when the controller is located in the instrument house for then only one long tube need go to the valve and one to the sensing unit. Since tubing and installations are costly and a saving of about $0.50 per foot is possible, we commend location of controllers in the instrument house, except where the control is critical or the distance excessive.

When the total distance is much greater than 200 feet, the quality of control becomes poorer and the adjustments more critical. We feel that the total (measuring plus controlling) tubing distance should preferably be no more than 600 feet except under conditions of great process stability.

Possibilities of Simpler Control Mode

At the 1949 Instrument Society of America Convention in St. Louis, David M. Boyd, Jr. presented a paper on "Process Control by Graphic Panel*," in which he gave some field-test data on flow-control systems and stated:

"A market appears for a small, simple, pre-engineered proportional speed floating controller, preferably one that could be mounted right on the control valve."

Such a controller would, of course, respond only to reset and have an infinite proportional band.

We were particularly interested in this proposal since it was identical to one made in 1940 by Dr. Donald P. Eckman, author of "Fundamentals of Instrumentation and Control", then in our employ and now at Case Institute of Technology. We carefully analyzed Eckman's work and thereupon instituted an additional series of tests during which we found that it would indeed be possible to apply simple adjustable-speed floating control to many flow applications.

Such a controller can be adjusted to give very fast corrections when needed, but the characteristics of the valve used become more important and, when and as these change materially, re-adjustment is required. Since many valves are required through wide ranges and conditions do not always remain constant and ideal, we consider the simple floating controller impracticable.

The idea, however, has merit and further work showed that with proportional-band-plus-reset controllers the automatic reset could be made to do most of the work and the proportional-band adjustment could be left fixed at some high value, such as 100 percent. Such a controller, from which the proportional-band adjustment has been removed, when connected to a valve in the same line as the measuring element and located at the valve will accomplish comparable results to that obtained by a controller with a full range of adjustments on both the reset and the proportional band under the same conditions.

For effective control, however, such a unit must necessarily be located at the valve, while the adjustable-band proportioning controller may with practically equal result be located in the instrument house. Since a fixed-band proportioning controller is a device which is essentially only suitable for use with flow control while an adjustable-band device of similar design is universally applicable and can be located anywhere within practical limits, we anticipate that practical instrument men will prefer to use the more universal controller for all installations.

Summary of Conclusions

To sum up then, our conclusions are:

(1) Recording instruments required to operate from diaphragm-type flow transmitters require damping.

(2) Control devices should receive undamped signals to obtain maximum response speed and rapid control recovery. Therefore the sensing element operating the controller should be separate from that operating the recording pen.

(3) When diaphragm-type transmitters are thus used with independent controllers, great improvements are possible both in respect to recovery-curve area and recovery time over the values fuond when mechanical transmitters are used.

The improvement ratio is greatest (92 percent) where both systems are locally mounted, but, even for distances of 300 feet, the improvement possible is in the order of 56 percent.

(4) To obtain maximum speed of control response, the distance between the meter through the controller to the diaphragm motor should be a minimum although we consider that this maximum response speed has little practical value in most of today's processes.

(5) Improvements due to change in controller location for given types of transmitters are relatively small but increase rapidly as total (measuring plus controlling) tubing distances above 400 feet are encountered.

(6) For practical purposes we may in most cases permit up to 400 feet total distance from the meter through the controller to the valve, and the controller may be mounted on or near the panel, thereby reducing installation and maintenance costs.

* I.S.A. Journal Section of *Instruments*, Vol. 22, No. 11, pp. 1054-1057, Nov. 1949.

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RICHLAND
R. A. Nederhood, 2003 Trippe St., Richland, Washington. Tel. 5-4442
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
J. J. Connors, 272 Elgin St., Sarnia, Ontario, Canada. Tel: 1970 W
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SECTIONS DATA

Continued from page 584

ST. LOUIS
W. G. Lee, 4710 Delor St., Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
Morris L. Conner, 925½ Sherman St., Toledo, Ohio. Tel: MA 9403
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Bartlesville, Okla. Tel: 6600 Ext. 501.
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab, White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel. 0167J
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 100 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

Symposium on Panel Board Design

A two-session, four-paper symposium on the "Philosophy of Panel Design" was conducted by the New Jersey Section ISA on April 13, 1951 at the Essex House Hotel in Newark, N. J. Total attendance was in excess of 300.

Papers and speakers were: "Human Instrumentation," Commander L. S. Beale; U.S.N. M.C. Office of Naval Research Special Devices Center; "Standardization of Panel Design," Robert L. Hurley, Jr., E. I. duPont de Nemours & Co.; "Comparative Costs of Conventional, Graphic and Condensed Instrument Panels," W. A. Hagerbaumer, Socony Vacuum Oil Co.; "The Future of Graphic Panels In Process Control," E. J. Grace, Jr., Sun Oil Co.

Commander L. S. Beale began the symposium with a presentation of the principles involved in presenting data to the human machine. This approach is usually termed *humanistic engineering*. Beale drew on the lessons which have been learned in the design of aircraft instrument panels. The difficulties of coordinating the man and the machine through a suitable control panel have resulted in considerable research on proper design principles for such aircraft panels.

Robert L. Hurley, Jr. treated the standardization of panel design by outlining some of the history of panel board practices at duPont and by mention of some of the practices which have been standardized to obtain the benefits of lower construction, equipment, and engineering costs. Hurley covered the factors which lead duPont into large scale use of the flow plan type control board. The extent to which such designs can be standardized was discussed, with remarks directed at probable future trends of such designs for batch and continuous processing units. The impression was gained that the flow plan type control center will, in large measure, supersede for most continuous processing units, the more conventional panel board with large instruments. An outstanding point made by Hurley was that such a graphic presentation of data to operators has proven of appreciable value for locations where inexperienced personnel were to be trained as process operators.

	Panel Length:
Conventional	22 ft.
Graphic	18
Condensed	12

W. A. Hagerbaumer presented a case history of the design of three types of control centers for a thermal reformer unit with fractionation facilities. The basis used in a comparative analysis of cost was that for all designs the same number of points were to be recorder, indicated, and controlled. The three types of control centers compared were called the *conventional*, the *graphic*, and the *condensed*. The conventional design utilized present conventional 12-in. dia. round-chart recorders and controllers. The graphic design utilized the newer, small strip-chart recorders which can be applied directly to the flow plan which is the background of the panel control board. The condensed design used the new small strip chart without the flow plan background, plus a number of multiple record instruments, to reduce the number of individual instruments on the board.

The cost comparison (rounded to the nearest $100) tabulated as follows:

Cost: material & equipment:	*Cost: material, instruments & control room space, contractor fees & overhead:*
$16,000	$24,400
15,800	23,400
14,900	20,800

At the evening session E. J. Grace, Jr. discussed the future of graphic panels in process control. Grace told of Sun Oil Company's recent installation of telephone type switching equipment for reducing the cost of wiring for installations involving a large number of thermocouple extension leads to control houses. Installations using up to 700 thermocouples in a single control center were described. A feature of such installations was the use of a scanning system tied into the critical thermocouples for signaling the operator.

The use of gamma radiation for the measurement of levels and the facilities installed by Sun Oil Company for handling the radium was treated. Grace discussed formative designs involving high-speed measuring and signaling devices to be used in an attempt to reduce sizes of control centers and to improve the quality of process control.

E. J. Grace, Jr., Sun Oil Co., presents paper before New Jersey Section's symposium on panel design.

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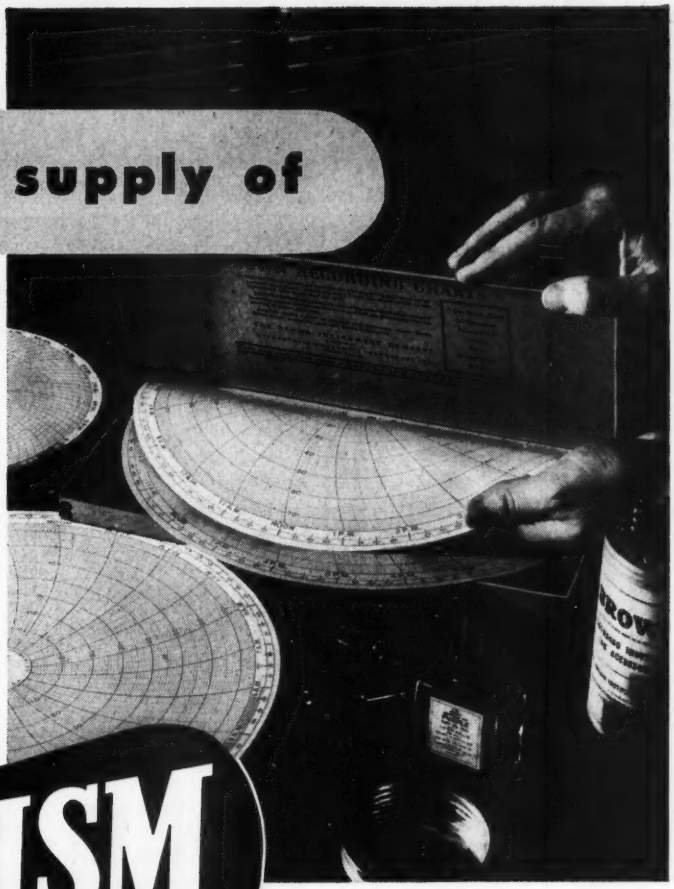

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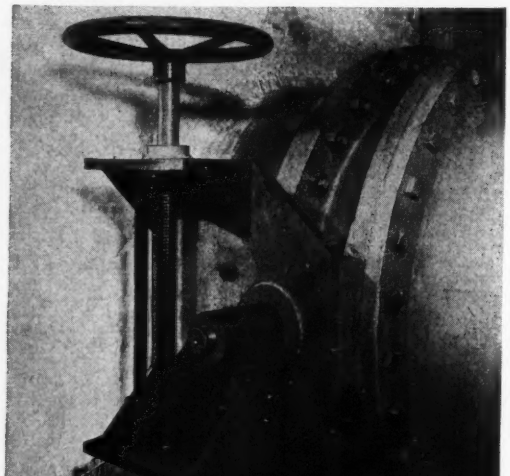

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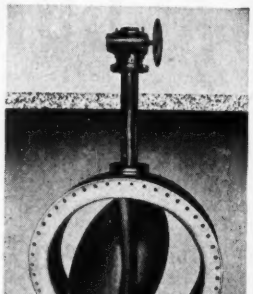

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Operation *of a* Telemetering System

Which Does Not Use Commercial Power *at* Transmitter

By W. L. MASHETER, Meter & Regulator Engineer, Southern Counties Gas Company

THE problem of operating telemetering equipment without the use of commercial power arose when it was decided to telemeter pressures at several points along the 30-in. natural-gas transmission line from Blythe, California to Los Angeles. The line, which is jointly owned by the Southern California Gas Company and the Southern Counties Gas Company of California, transmits gas from the El Paso Natural Gas Company's transmission line, which terminates at the California border at Blythe, to our dispatching station at Spence Street, Los Angeles, California. It was desired to telemeter the inlet and outlet pressure from the three pressure-limiting stations located at Shaver Summit, Whitewater, and Olinda, to the recording receivers located at the Blythe Compressor Plant, Southern California Gas Company's Colton Office, and the Spence Street Dispatching Station respectively. Commercial a-c. power was available at the receivers at Blythe, Colton Office, and Spence Street Dispatching Station at the Olinda Pressure Limiting Station, but no commercial power was available at the other two stations.

By telemetering the inlet and outlet pressures at the pressure-limiting stations to the dispatching and operating stations, it was possible for the operating personnel at these stations to keep a constant check on the operation of the limiting stations and to compute the line pack available for withdrawal on peak loads or available for storage during light gas-consumption. The pressure-limiting stations, as the name implies, limit the pressure in the succeeding section of line to a maximum set pressure; therefore, thinner walled pipe could be used in the line in those sections nearer Los Angeles where the pressure would always be considerably lower when the line was operating at or near maximum capacity.

*Presented at the regular meeting of the Southern California Meter Association, April 18, 1951.

June Meeting: Thursday the 21st, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30. Meeting at 8:00 p.m.

Feature: Industrial Engineering and Personnel Problems of Manufacturing License Plates at Folsom, by Robert C. Dean.

Telemetering System

The telemetering system used was made up of (1) Bristol metameter equipment, (2) a leased telephone circuit for transmitting the impulses, (3) a six-volt chronometrically governed d-c. motor for powering the metameter-transmitter cam drives, and (4) a pneumatic switching device for alternately switching the pressure measured and transmitted by the metameter transmitter.

The Bristol equipment.—Although there are a number of telemetering systems on the market, our Company uses the Bristol metameter telemetering equipment. This equipment uses the impulse system and requires that the cam in the transmitter and the gear mechanism in the receiver be driven at the same speed. The standard equipment is run at this constant speed by a synchronous Telechron-type motor, which is similar to the electric motors in electric clocks. A-c. power was available at the receivers, but no a-c. power was available for the transmitters at two of the stations. The standard 60-rpm. Telechron motor used in the transmitter requires 6 watts a-c. power and has a torque rating of 0.24 inch-ounces at 60 rpm. The motor rotates the cam at 4 rpm. through gearing. The equipment also requires use of a single circuit between the transmitter and the receiver for carrying d-c. power (40 milliamperes for standard equipment).

Telephone lines.—In the original preliminary planning of the 30-in. pipeline, telephone service was approved where economically feasible at the limiting stations, and the telephone company was approached on the possibility of leasing a line for telemetering purposes as well as for telephone use. Fortunately, telephone lines were within reasonable distances from the limiting stations and it was possible to obtain circuits at a reasonable first cost for extending the telephone line and at a reasonable monthly rental charge.

No power lines were close to either of the stations, and the preliminary estimates of the cost of running power lines to the stations were so high that this solution was ruled out of further consideration.

The telephone company was approached on the idea of transmitting the 6 watts of a-c. power necessary to run one telemeter transmitter over a leased telephone circuit. However, they not only frowned on transmitting the a-c. power, but had no lines available with sufficiently low resistance to permit transmitting the power without exceeding their standards of maximum voltage. Of course, the charges for this service, if available, would have been considerably more than for a single d-c. circuit.

Driving the cam.—In considering possible means for driving the cam of the metameter transmitter, one of the points which had to be considered was that it was desired to service the station only once a week and, therefore, any type of equipment adopted must operate for that time without attention. A number of possible methods of driving the cam at constant speed were considered, including use of a spring drive, falling weights, air motors, and d-c. motors operating from batteries. No commercially built spring drive could be found which would rotate the cam at 4 rpm. and also run for 7 days without rewinding. Likewise, no commercially manufactured drive using falling weights could be found. It was found that before World War II a company had developed a pneumatic motor drive for rotating recording charts, which was designed to operate from gas pressure. However, it was found that this motor had not worked as expected in the field and therefore was no longer manufactured. A number of types of d-c. motors were considered, but most of them could not maintain a sufficiently constant speed.

The initial installation utilized a cam drive consisting of a 6-volt d-c. motor manufactured by the Amglo Corporation. The factory specifications stated

that the motor used 0.25 to 2 watts and had a rated torque of 3.3 inch-ounces at 60 rpm. The motor had a polarized magnetic drive with the electrical impulses timed by a vibrating reed acting at resonant frequency. The current withdrawal was found to vary little with the load, but varied considerably between different motors, even though they had identical specifications. One had a current withdrawal of 60 milliamperes, another of 95, and a third of 120. The speed varied considerably with load, temperature, and voltage, which resulted in a rather wide line on the recording chart. The motor gave usable results, although not as good as was desired. Some difficulty was experienced with the bearings of the motor wearing out after several months' service. However, the motor was relatively cheap and we were satisfied to replace the motors until something better could be found.

About a year and a half ago, an advertisement was noted which stated that the A. W. Hayden Company was making a chronometrically governed d-c. motor designed for continuous service. These motors are rated at 0.5 inch-ounces of torque at 60 rpm., and the manufacturer claims that they will operate satisfactorily with a plus or minus 20-percent voltage variation, a temperature variation of minus 50 to plus 150 F., and a load variation of 0 to 200 percent. The motors have a current withdrawal of 40 to 70 milliamperes. The speed of the motors is controlled by a balance wheel and escapement unit, which acts to control the make and break contacts which supply the impulses to drive the motor. A 6-volt motor was purchased for a trial and was found to maintain a more constant speed than the Amglo motor. As a result of the test on the motor, the 2 stations were equipped with Hayden chronometrically governed d-c. motors. The 2 motors have been in service for over a year and to date only one motor has developed trouble. It was returned to the factory for repairs. Two spare motors are kept in the Repair Shop to avoid delay in putting the transmitter back in service if one of the motors should develop trouble.

D-C. Power Source

Two sources of d-c. power were tried with the original installation, which was made with the Amglo motor. Initially, six 250 ampere-hour 1.2-volt carbon-cell batteries were used in series. Computations based on the rated capacity of these batteries indicated that they would last approximately 3 months. However, they exhibited considerable voltage drop with continued current withdrawal and more cells had to be added after about a month to keep the motor running. The voltage drop caused the speed of the Amglo motor to be slowly reduced and, therefore, necessitated frequent adjustments in order to obtain a usable chart at the receiver end. The carbon-cell batteries

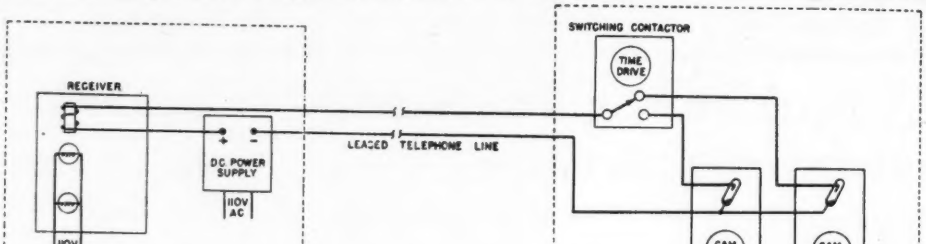

FIGURE 1 CIRCUIT SWITCHING TAKING PLACE AT TRANSMITTER

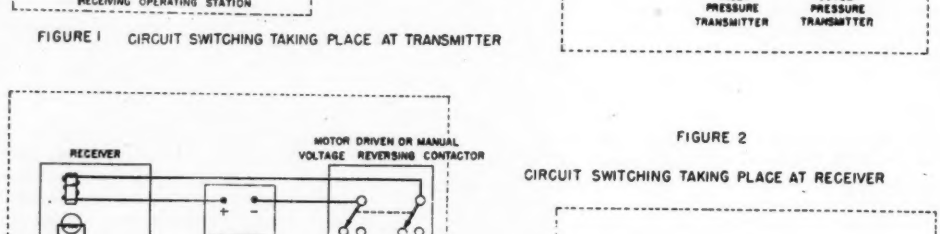

FIGURE 2

CIRCUIT SWITCHING TAKING PLACE AT RECEIVER

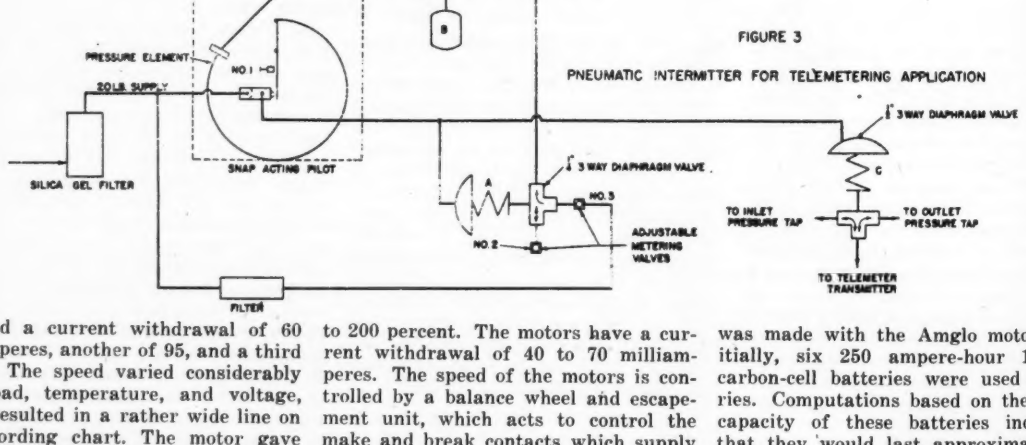

FIGURE 3

PNEUMATIC INTERMITTER FOR TELEMETERING APPLICATION

were found also to be a rather expensive source of power because they could not be recharged, and they cost as much as a good automobile storage battery, which is rechargeable. The second source of power consisted of a standard 6-volt automobile storage battery. Although the storage battery also gave a drop in voltage with continued current withdrawal, it had better voltage characteristics than the carbon-cell batteries and ran the motor satisfactorily for two weeks without recharging. When the Hayden motors were installed, the same 6-volt standard storage batteries were used successfully for a time. When new, they ran the motor for a month without recharging, but they were usually recharged every two weeks.

Last year, some nickel-cadmium batteries were purchased and put into use with the Hayden motors. These batteries use an alkaline electrolyte and are advertised for long life and low maintenance. Units of five 1.3-volt 30 ampere-hour cells were purchased. These batteries ran the motors for two weeks initially, but at the present time they run the motors only for about a week before requiring recharging.

Switching System

It was decided to telemeter two pressures from each of the pressure-limiting stations. As it was not necessary to have a continuous record of the pressures, we decided to telemeter the two pressures at alternate intervals over one leased circuit. In order to do this, it was necessary that a switching device be provided.

Two types of electrical circuit switching systems were considered. The first system, which uses two metameter transmitters and an electric circuit-switching device at the transmitter end, is shown in Fig. 1. This method requires three motors—two for the transmitters and one for the switching device—and, therefore, requires approximately three times the power needed for running one transmitter. The second system considered uses two motors to drive the metameter transmitters, and utilizes a d-c. reversing switch, either manual or motor driven, at the receiving end. This system is shown in Fig. 2. It might be possible to use only one motor to supply the driving power for either the three operations or the two operations of these two systems, but this would necessitate use of expensive custom-designed transmitting equipment.

Pneumatic intermitter.—The system which is being used has a pneumatic-pressure switching-device which operates from gas pressure. Therefore, the system has only one motor, which drives the cam of the single pressure transmitter. The switching device which alternately switches the inlet and outlet pressures automatically to the single telemeter transmitter, is shown in Fig. 3. It consists of a Fisher Wizard snap-acting pilot, which is an integral part of the diaphragm case of a ½-in. three-way diaphragm control valve, a second three-way diaphragm control valve, a volume chamber, and adjustable needle-valve bleed orifices.

The snap-acting pilot is constructed so that it supplies either full operating "on" pressure or zero "off" pressure. It can be adjusted so that "on" control is obtained at one element pressure and "off" control is obtained at a second element pressure. Referring to Fig. 3, the snap-acting pilot, D, puts the 20-psig. supply pressure on the heads of the three-way diaphragm control valves, A and C, when the pressure in the volume chamber, B, drops to 5 psig. It maintains this 20-psig. pressure until the pressure in chamber B reaches 10 psig. At this pressure the snap-acting pilot, D, opens the needle valve and bleeds the pressure on the diaphragms of valves A and C to atmosphere. With 20 psig. on the head of control valve A, pressure is routed through needle valve 3 into volume chamber B from the 20-psig. supply. This slowly builds up the pressure in the volume chamber, B, to 10 psig. As soon as the pressure in the volume chamber, B, reaches 10 psig. the snap-acting pilot bleeds the pressure off the diaphragm of three-way diaphragm valve A, causing it to move its valves so that volume chamber B is connected with needle valve 2, which slowly bleeds the pressure to atmosphere until it reaches 5 psig. The cycle is then repeated. When there is 20-psig. pressure on the head of three-way diaphragm valve C, the telemeter-transmitter pressure-element is connected to the inlet side of the limiting station; when no pressure is on the head of the diaphragm, the transmitter pressure-element is connected to the outlet side of the limiting station. The metering needle-valves 2 and 3 are adjusted to switch the pressures at approximately 10-minute intervals. To date, the equipment has worked satisfactorily and has maintained the time interval without readjustment.

The conclusions which we have drawn from our experience with telemetering without commercial power are as follows: (1) The A. W. Hayden chronometrically-governed d-c. motor gives the best results of any d-c. motor tested, (2) standard 6-volt automobile storage batteries are the most satisfactory source of power tried to date, and (3) two pressures can be alternately transmitted satisfactorily with only one transmitter (assuming both pressures can be measured by the same pressure element) by using a gas-pressure-actuated timing device.

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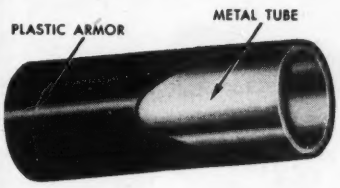

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T-380 THERMOWELLS. 16-page catalog illustrates and describes maker's thermowells including threaded, ground-joint, finned-stem welded-tubing and -socket models, and bar-stock models; lists specifications, engineering diagrams, and corrosion data.—Karn Chemical Equipment Co., 518 Dickson Ave., Pittsburgh 2, Penna.

T-381 STEAM AND AIR TRAPS. 50-page catalog features article "Basic Power Plant Figuring"; includes data and price list covering maker's steam and air traps, reducing valves, pressure regulators, pump governors, temperature regulators, and feed-water controls.—Squires Steam Specialties, 18502 Syracuse Ave., Cleveland, Ohio.

T-382—INTERFEROMETER. 4-page bulletin (revised September 1950) contains a complete general index to literature on maker's products (interferometers, microscopes, spectrometers, comparators, etc.) as well as those under preparation.—The Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

T-383 MACHINE-CUT SURFACE-FINISH STANDARDS. 8-page Bulletin illustrates and describes maker's machine-cut stainless-steel specimens for surface-quality control; discusses contents of two sets; includes definitions, specifications, ratings, symbols, and typical examples.—University Machine Div., Baird Associates, Inc., Cambridge, Mass.

T-384 ELECTRICAL INSTRUMENTS. 64-page Catalog 48 illustrates and describes distributor's line of laboratory and portable test instruments, panel and switchboard instruments, pyrometer and associated equipment, service instruments, transformers, rectifiers, controls, and miscellaneous equipment.—Electro-Tech Equipment Co., 309 Canal St., New York 3, N. Y.

T-385 DIE-STAMPING WIRE CIRCUITS. 16-page brochure illustrates and describes "Mass Production Die Stamping of Wired Circuits"; discusses detailed analysis, maintenance, and potential applications.—Franklin Airloop Corp., 43-20 34th St., Long Island City 1, N. Y.

T-386 PUMP CONTROLS. 4-page Bulletin 1201 illustrates and describes maker's "Mototrols" pressure-operated pump controls for elevated tank systems with two or more pumps.—Automatic Control Co., St. Paul 4, Minn.

T-387 FORCE INDICATOR. 4-page bulletin illustrates and describes maker's 12 models of force indicators; includes typical applications and operation.—Hunter Spring Co., Lansdale, Penna.

T-388 FURNACE INDICATOR. 4-page Bulletin 5101 illustrates and describes maker's "Wyd-angle" smoke periscope for marine and industrial use, and "Cat's-eye" furnace indicator for viewing furnace performance from any point in boiler room.—Ess Specialty Corp., Bergenfield, N. J.

T-389 LATHE OPERATION. 128-page, 50th Edition of lathe-operator's handbook "How to Run a Lathe" discusses the history and development of the screw-cutting lathe, setting up and leveling lathe for use, lathe tools and their applications, cutting screw threads, clutch work, special classes of work, etc. Paper-bound copy 25 cents, imitation leather $1.00.—South Bend Lathe Works, South Bend 22, Ind.

T-390 PANEL INSTRUMENTS. 22-page catalog illustrates and describes maker's electrical indicating instruments for small power-unit panels, industrial test units, communication equipment, etc.; includes construction, range, engineering diagrams, and price list.—Beede Electrical Instrument Co., Penacook, N. H.

T-391 TIMING MOTORS. 8-page Catalog 322 illustrates and describes maker's electric timing motors; includes specifications, features, and operation.—Haydon Manufacturing Co., Inc., Torrington, Conn.

T-392 INSTRUMENTATION COURSES. 8-page pamphlet discusses CRL courses of basic instruction and advanced training in theory and practical application of AM and FM radio, television, and industrial instrumentation; veteran approved.—The CRL School of Electronics, 29 Allyn St., Hartford, Conn.

T-393 ELECTRONIC SHORTCUTS. 54-page booklet "Electronic Shortcuts for Hobbyists" gives 24 simplified crystal-diode applications for the home hobbyist, experimenter, and model maker; 25 cents postpaid.—Sylvania Electric Products Inc., Emporium, Penna.

T-394 VOLTAGE DIVIDER. 4-page Bulletin A-2 illustrates and describes maker's "Type W" 2-watt rheostat voltage-divider; includes specifications, construction and characteristics.—International Resistance Co., 401 N. Broad St., Philadelphia 8, Penna.

T-395 ANALOG DIGITAL CONVERTER. 4-page bulletin and engineering diagram illustrates and describes maker's analog digital converter; discusses application, operation, and price.—Genisco, 2233 Federal Ave., Los Angeles 64, Calif.

T-396 TOOLMAKER'S MICROSCOPE. 8-page Bulletin 147-50 illustrates and describes maker's microscope for precision shop measurements; discusses 30 features as well as operation, general description, specifications, and accessories.—Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

T-397 SPECTROPHOTOMETER. 8-page Bulletin 151-A illustrates and describes maker's "Weichselbaum-Varney Universal" spectrophotometer, a flame photometer for rapid, absolute quantitative determination; includes schematic diagrams of operation.—Scientific Instruments Div., Fearless Camera Corp., 1180 W. Olympic Blvd., Los Angeles 25, Calif.

T-398 THICKNESS MEASUREMENT GAGE. 16-page Catalog MY-50-1 illustrates and describes maker's "50 Series Measuray" non-contact X-ray gage for continuous or intermittent measurement of strip or sheet stock, stationary or in motion.—Measuray Sales Div., Sheffield Corp., Dayton 1, Ohio.

T-399 POLAROGRAPH. 32-page house organ, Vol. 4, Winter 1950-51 issue of "Scientific Apparatus & Methods," features article "The Polarograph in the Insecticide Industry"; includes catalog section on scientific apparatus, radiation-measuring equipment, combustion equipment, centrifuges, etc.—E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.

T-400 ELECTRONIC COUNTER. 4-page bulletin illustrates and describes maker's "Model 554 Eput" (Events-Per-Unit-Time) high-speed

electronic counter combined with accurate time base; includes features, design, operation, specifications, construction, and applications.—Berkeley Scientific Co., 6th & Nevin Aves., Richmond, Calif.

T-401 PANEL BOARDS. 4-page Bulletin 143-10M-51 illustrates and describes maker's instrument panel boards.—Falstrom Co., 99 Falstrom Court, Passaic, N. J.

T-402 PETROLEUM VAPOR FILTER. 4-page Bulletin SC-10.X3 illustrates and describes maker's "Vape-sorber" for continuous removal of petroleum vapor, dirt, and liquids from compressed air and other gases; no moving parts.—Selas Corporation of America, Philadelphia 34, Penna.

T-403 VISCOSITY MEASUREMENT. 12-page Catalog 88 illustrates and describes maker's "Viscorator" for continuous viscosity measurement and control; discusses viscosity measurement, one- and two-float instrument, and typical installations.—Fischer & Porter Co., Hatboro, Penna.

T-404 FRACTIONAL H-P MOTORS. 4-page page bulletin illustrates and describes maker's fractional h-p. electric motors; discusses features, specifications, and engineering data.—John Oster Manufacturing Co., Racine, Wis.

T-405 TECHNICAL TUBE MANUALS. 4-page bulletin illustrates and describes maker's publications for use as classroom and student aids; includes radio instruction course, lesson folders, radio symbols chart, color code cards, and college electronic-laboratory test equipment.—Merchandising Dep't., Sylvania Electric, Emporium, Penna.

T-406 HIGH-VOLTAGE MEASUREMENT. 16-page house organ, Vol. 16, No. 3 issue of "The C-D Capacitor," features article on technique of high-voltage measurements; includes regular feature "Radio Trading Post."—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

T-407 A-C MOTORS. 4-page Price List 26 lists maker's synchronous a-c. motors, d-c. motors, clock movements, and timers.—Haydon Manufacturing Co., Inc., 245 E. Elm St., Torrington, Conn.

T-408 SMALL-PARTS CLEANING MACHINES. 4-page brochure illustrates and describes maker's small-parts cleaning machines, cleaning and rinsing solutions, flexible-shaft equipment, polishing motors, crystal cement, mallets, hammers, and rust remover.—L. & R. Manufacturing Co., 577 Elm St., Arlington, N. J.

T-409 BREAKER-TYPE D-C. AMPLIFIER. 4-page brochure illustrates and describes maker's "Model 10" breaker-type d-c. amplifier to replace high-sensitivity galvanometers; discusses performance characteristics.—Liston-Folb Instrument Co., Inc., P. O. Box 780, Stamford, Conn.

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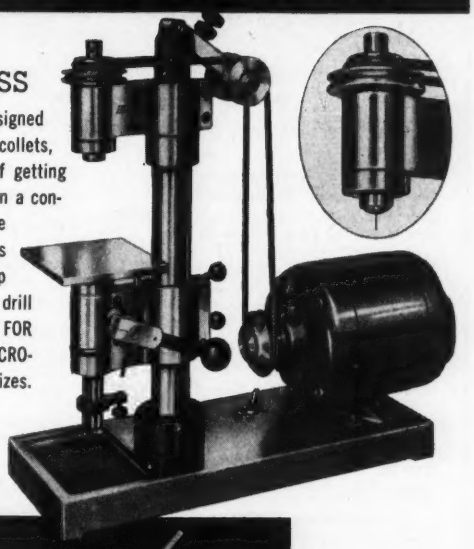

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The Engine Indicator—Its Design, Theory and Special Applications by K. J. DeJuhasz, 1934, cloth, 5½" x 8¼", 243 pages. Price $2.00.

Heat Inertia in Problems of Automatic Control of Temperature by Victor Broida, 1950, paper, 5¼" x 8¼", 61 pages. Price $1.00.

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T-413 TERMINALS. 12-page Catalog W illustrates and describes maker's glass hermetic, alumina lead-through hermetic and multiple glass-metal terminals, metallized products, electronic housings, and insulators.—T. C. Wheaton Co., Millville, N. J.

T-414 INDUSTRIAL ELECTRONIC COMPONENTS. 208-page Catalog 126 lists complete lines of radio, TV, and industrial electronic equipment including amateur equipment, condensers, transformers, galvanometers, voltmeters, plugs, tubes, etc.—Allied Radio, 833 W. Jackson Blvd., Chicago 7, Ill.

T-415 PRECISION INSTRUMENTS. 8-page brochure contains a survey of maker's precision instruments of linear, coordinate, angular, spectral, and photometric measurements as well as dividing machines, optical parts, and special apparatus.—Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago, Ill.

T-416 FLOW MEASUREMENT. 32-page Bulletin 351-2 discusses the principle of flow measurement, primary devices, recorders, indicators, meter types, integrators, square-root planimeters, charts, piping layouts, pneumatic transmissions, etc.—The Foxboro Co., Foxboro, Mass.

T-417 VALVE. 4-page Bulletin 304 illustrates and describes maker's safety valve for industrial press and similar applications; discusses elimination of use of springs and use of clapper type solnoid.—Ross Operating Valve Co., 120 East Golden Gate, Detroit 3, Mich.

T-418 ABRASION RESISTANCE. 4-page house organ Vol. 31, No. 2 issue of "The Motorgram," features article "Measuring Abrasion Resistance of Surfaces," and a discussion of common motor trouble and causes.—Bodine Electric Co., 2244 W. Ohio St., Chicago 12, Ill.

T-419 ELECTRIC CLOCK MOVEMENTS. 4-page Catalog 324 illustrates and describes maker's "Series 1800 and 1802" electric clock movements; lists complete specifications.—Haydon Manufacturing Co., Inc., Torrington, Conn.

T-420 WAVEGUIDE MEASURING EQUIPMENT. 4-page house organ, Vol. 2, No. 6 issue of "hp Journal," features article "The 'hp' Program for Waveguide Type Measuring Equipment"; includes specifications and summary of equipment.—Hewlett Packard Co., 395 Page Mill Road, Palo Alto, Calif.

T-421 INTERCOMMUNICATING SYSTEMS. 16-page Catalog 35 illustrates and describes maker's intercommunicating systems for manual of mechanical operation; discusses specifications, accessories, standard types, outline and mounting dimensions, and typical wiring diagrams.—Henschel Corp., Amesbury, Mass.

T-422 RESISTORS. 4-page Bulletin B-5 illustrates and describes maker's "Type BW" insulated wire-wound resistors for low-range requirements; includes charts and graphs.—International Resistance Co., 401 N. Broad St., Philadelphia 8, Penna.

T-423 ELECTRICAL TESTING INSTRUMENTS. 4-page house organ Vol. 7, No. 1 issue of "Biddle Instrument News," features articles in applications of maker's electrical testing instruments, speed-measuring instruments, laboratory and scientific equipment.—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

T-424 TRANSFORMERS. 4-page Technical Data Sheet No. 3 illustrates and describes foreign-made "Partridge" transformers; discusses winding, load, self capacity, phase characteristics etc.—Distributor: Unio Trading Corp., 27 Park Ave., New York 17, N. Y.

T-425 OSCILLOSCOPE. 4-page bulletin illustrates and describes "Model 117 Labscope" cathode-ray oscilloscope; includes applications, description and specifications.—Distributor: Brujac Electronic Corp., 103 Lafayette St., New York 13, N. Y.

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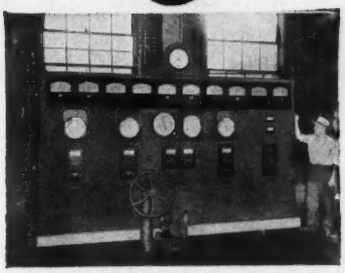

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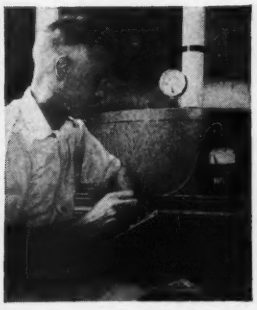

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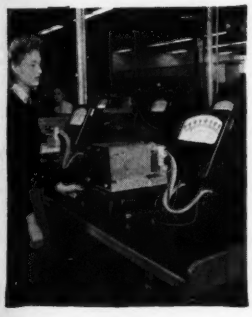

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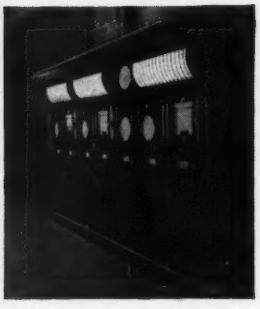

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